LIVERPOOL GEOLOGICAL ASSOCIATION.

TRANSACTIONS.

V. 1

SESSIONS 1880-1881.

LIVERPOOL:
PUBLISHED BY HENRY YOUNG, 12, SOUTH CASTLE STREET.

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LIVERPOOL GEOLOGICAL ASSOCIATION,

FREE LIBRARY, WILLIAM BROWN STREET, LIVERPOOL.

Council.

PRESIDENT.

HENRY BRAMALL, M. INST. C.E.

VICE-PRESIDENT.

THOMAS SHILSTON, M.I.N.A.

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GEORGE LEWIS. | THOMAS BRENNAN.

DANIEL CLAGUE.

TREASURER.

WILLIAM H. WALKER.

Botanic View, Smithdown Lane, Liverpool.

SECRETARY.

CHARLES E. MILES.

16, Willow Bank Road, Higher Tranmere, Cheshire.

THIS COUNCIL WILL CONTINUE UNTIL OCTOBER, 1881.

INDEX.

The Authors are alone responsible for the facts and opinions expressed in their Papers.

LAWS

OF THE

LIVERPOOL GEOLOGICAL ASSOCIATION,

Established 3rd June, 1880.

RULES PASSED 15TH NOVEMBER, 1880.

OBJECT.

The object of the LIVERPOOL GEOLOGICAL ASSOCIATION *is to promote the study of Geology and its allied Sciences.*

RULES.

I

n of rs. That every Candidate for membership shall be proposed and seconded by two members of the Association, and ballotted for at the next Ordinary meeting; and the consent of three-fourths of the members then present shall be necessary for the admission of such Candidate.

The proposal shall be made on Form A, which must be filled up and lodged with the Secretary one week before the meeting at which the Candidate is to be proposed. The proposal form shall be submittsd to the Council, and the Secretary shall report to the members any remarks the Council may deem it expedient to make thereon.

II.

tion. Every member shall pay an annual subscription of Five Shillings, payable on the 1st October, or in the case of a new member, within one mcnth after election. Any member not paying the subscription within three Calendar months, after being twice informed by the Secretary that it is due, shall no longer be considered a member of the Association.

III.

Officers. The officers of the Association shall be a President, Vice-President, Treasurer, Secretary, and five other members, who together shall constitute the Council to manage and direct the affairs of the Association. Five to form a quorum. The officers shall be elected at the Annual Meeting, to be held in October; retiring officers shall be eligible for re-election. Any vacancy occurring during the year shall be filled up by the Council.

IV.

Accounts. The Treasurer's Financial Statement shall be presented to the Association, with the Annual Report, after having been duly audited by two members proposed, seconded, and elected at the last meeting of the Session.

V.

Ordinary Meetings. The Ordinary Meetings shall be held on the first Monday in each month, at Eight o'clock in the evening. The order of proceeding at such meetings shall be :—

1.—The ordinary business of the Association.

2.—Miscellaneous Communications.

3 —Original Papers or Communications, to be followed by discussion thereon.

4.—Announcement of business for the next meeting.

VI.

Special Meetings. A Special Meeting may be called at any time by the Council; and they shall be bound to call such a meeting on receipt of a requisition signed by not less than ten members, stating the purpose for which the meeting is to be convened. Seven days' notice of a Special Meeting shall be given to every member, such notice to specify the business to be considered, and the meeting shall be held within twenty-one days after the receipt of the requisition. No other business shall be considered at a Special Meeting except that for which it has been called.

VII

Field Meetings. Field Meetings shall be held at places of Geological interest, but none of the private business of the Association shall be transacted on such occasions.

VIII.

Voting. The Votes on any question brought before the Association shall be taken by a show of hands, except those for the election of officers and new members, which shall be taken by ballot.

IX.

Manuscripts of Papers. The Manuscript of every Paper read, or a clear and legible copy thereof, written on foolscap, shall become the property of the Association, and shall be placed in the Library for the use of the members.

X.

Expulsion of Members. In case of non-compliance with the Rules of the Association, or misconduct by any member, such member may be requested by the Council to resign. Failing to do so the Council may bring the case before a meeting of the Association which shall deal with it as may seem expedient.

XI.

Visitors. Every member may introduce a friend at any Ordinary or Field Meeting of the Association, provided, however, that no person qualified to become a member be admitted as a Visitor more than twice in the same year.

XII.

Addition to or Alteration in Rules. No addition to or change in these Rules shall be made, except by a majority of not less than two-thirds of the members present at a Special Meeting to be convened for that purpose.

LIVERPOOL GEOLOGICAL ASSOCIATION.

FORM A.

M ....

....

being desirous of admission to the Association, We, the undersigned, recommend him as a proper person to become a Member.

Dated..................................18

Proposed by..

Seconded by..

Date Proposed..

Date Elected ....

Signature of Candidate...

........................Secretary.

REGULATIONS FOR THE ADMISSION OF MEMBERS.

RULE 1.—That every Candidate for membership shall be proposed and seconded by two members of the Association, and balloted for at the next ordinary meeting; and the consent of three-fourths of the members then present shall be necessary for the admission of such Candidate.

The proposal shall be made on Form A, which must be filled up and lodged with the Secretary one week before the meeting at which the Candidate is to be proposed. The proposal form shall be submitted to the Council, and the Secretary shall report to the members any remarks the Council may deem it expedient to make thereon.

RULE 2.—Every Member shall pay an annual Subscription of Five Shillings, payable on the 1st october, or, in the case of a new member, within one month after election. Any member not paying the Subscription within three calendar months, after being twice informed by the Secretary that it is due, shall no longer be considered a member of the Association.

LIVERPOOL GEOLOGICAL ASSOCIATION.

At the Meeting on Monday, 13th December, 1880, Mr. Bramall. M. Inst., C,E., President, in the Chair, the following were proposed as members :—Messrs. T. Mellard Reade, F.G.S., M. Inst., C.E., William Semmons, A. Norman Tate, F.I.C., Herbert Fox, W. H. Miles, J. J. Williams, William Martin, John D. Jones, Isaac Baruchson, J. D. Howard, Mrs. T. Shilston, and Miss L. Williams.

A vote of thanks was passed to J. A. Picton, Esq., and the Library Committee, for their kindness in granting the use of a room in the Free Library in which to hold the Meetings of the Association.

The following is an abstract of the Opening

ADDRESS BY THE PRESIDENT.

In connection with the Liverpool School of Science, classes have for several years been held in Geology and Mineralogy, Mr. William Semmons being the Lecturer.

Permeated with a love of these sciences, of which he has made a life-long study, and possessing an excellent collection of specimens, Mr. Semmons has also the gift of kindling the enthusiasm of his students, and remarkable success has attended his labours, as the results of the examinations held by the Science and Art Department testify. It was with feelings of regret that the Students heard the announcement at the beginning of this year, that owing to business arrangements Mr. Semmons would have to sever his connection with his classes, and a very general desire was felt that some means should be devised to extend and develope the knowledge already acquired, and to cultivate the study of Geology and its allied sciences. There being already in

existence in Liverpool, a Geological Society, the most obvious means of accomplishing the desired object was by the formation of a new class of Members, such as exists in several learned Societies, to be termed "Students," and such a proposal was made to the Council of that Society, but was rejected by them.

It was then decided to form a new Association, and a Committee was appointed, who framed the code of Rules which has been submitted to and approved by you. The Committee also applied to the Library Committee, through their Chairman, J. A. Picton, Esq., for the use of a room in which to hold the monthly meetings of the Association, and the request was granted with a liberality, and kindly consideration for which we all feel deeply indebted to them.

While awaiting the decision of the Council of the Liverpool Geological Society, arrangements were made to hold meetings and make excursions during the summer months, and it may be of interest to briefly relate what has been done.

The first Excursion was on the 3rd June last to Flaybrick Hill, under the guidance of Dr. Ricketts, F. G. S., when some Glacial striæ in the rocks of that neighbourhood were examined; and on the 26th of the same month several of the members accompanied the Liverpool Geological Society in an excursion to Dingle Point under the guidance of Mr. G. H. Morton, F. G. S.

A meeting was held at the Free Library on 1st July, when Mr. Jeffs read an elaborate paper on the Geology of Charnwood Forest.

On the 3rd July, Mr. Morton accompanied the members on a visit to Storeton Quarries, and at the meeting on the 5th August, he kindly attended and gave a description of the leading features of the Geology of that district; which was followed by a paper on the Geology of West Kirby, by Mr. C. E. Miles.

Mr. Hall, F. G. S., led an excursion to the Forest Beds, on the shore at Leasowe, on the 28th August, afterwards most hospitably entertaining the members at his house.

At the meeting on the 2nd Sept, Mr. Mellard Reade,

F.G.S., delivered an Address on the Post-Glacial deposits of West Lancashire and the Forest Beds at the mouth of the Alt, illustrated by a fine series of Maps and Sections which he has prepared of these deposits; and on the 18th he guided the members over the District, and afterwards entertained them at his house, where a very pleasant evening was spent in inspecting his collections.

An excursion took place on the 11th Sept., to Oldham, where Mr. James Nield met and kindly conducted the party to a quarry on Oldham Edge, where a remarkable assemblage of erect fossil trees has recently been discovered; and he also took us to see a deposit of Peat in the Boulder Clay which he considers to be of the age of the Glacial Period.

Mr. Shilston read a paper on the Bone Caves at Brixham, at the Meeting held on the 11th October.

On the 9th and 23rd of October, the collection of Mr. Morton was visited, and he kindly explained and exhibited the more interesting specimens, and afterwards entertained the members.

The meeting on the 15th November was occupied in passing and adopting the Rules and electing Officers for the Session.

Since June we have had five Meetings, four Papers read, six Excursions, and two visits to a Museum.

The object for which this Association has been formed is defined in our Rules to be to promote the study of Geology and its allied Sciences; and we propose to attain this object by meeting to hear papers read and discussed, and our success will largely depend upon the willingness displayed by members to write and read papers. It no doubt occurs to some of you, that you would gladly write a paper, but fear you have nothing new or striking on which to write. But it is by no means necessary that every paper shall record some newly discovered fact, or startling and original theory. On the contrary papers on well known facts frequently elicit most instructive and interesting discussions. And what a wide range of subjects

our Science offers from which to choose a theme. Pardon me if I glance hurriedly at some of them.

Since Lyell settled the science of Geology on the secure foundation on which it has since been built, it has been defined as the study of those agencies which have been at work in modifying the crust of the Earth. What are these Agencies?

The first and most obvious is Denudation. Everywhere we see this going on, rocks being ground down, disintegrated by atmospheric influences, by frost, and ice, by rains and winds, by glaciers and rivers, and by the sea. Valleys, River channels and Lake basins are carved out, and soils formed; and how?

But if we have destruction, so we have reconstruction, detritus and sediment carried by rivers and ocean currents, spread out in beds to form future lands.

Sea and land have oscillated in their relative levels; if we walk along the shores we see sunken forests, and raised old sea beaches. Inland we find Terraces, Escarpments, and Hill side Caves. How have these changes of level been brought about? and what may have been the effects of these variations in areas of land and sea upon the climate of different regions at varying epochs of Geological time?

Now and then we are startled by accounts of fearful Earthquakes, and we read of Volcanoes pouring forth flames and ashes, and great floods of melted rocks, of mud, and hot water, and although we in this Island have no practical acquaintance with these terrible throes of nature, we see their record written in the rocks that surround us. We have lava sheets and dykes, igneous rocks that have burnt and scorched the beds they have passed through; we have great deposits of volcanic ashes, and, like a lingering remnant of plutonic regards, we still have hot and mineralised springs. In every direction we find the rocks heaved and faulted; in many cases metamorphosed, cleaved, contorted, foliated, bent, jointed, lying at all angles of dip, traversed by Veins, filled with ores and *substances foreign* to the rocks they pass through. What

a wide range of deeply interesting phœnomena to write and think about, and to discuss together!

If we examine most of the formations of sedimentary rocks we find the remains of Organic nature fossilized, a record, so to speak, of the Succession of Life upon the Earth. True, it is a very imperfect and fragmentary record, and one which must ever remain so, from the very nature of the conditions under which it is possible for delicate organisms to be preserved; but new discoveries continue to be made, and many missing links have been found; and since Smith at the beginning of this Century pointed out the value of fossils as a means of determining the relative ages of beds, their fossil contents have afforded the basis of the Classification of Rock formations adopted universally by Geologists. It is interesting to inquire how have these organisms been preserved; and what were the conditions which obtained when they lived and died, and when the rocks containing them were formed? And how far do they afford support to the Darwinian Theory of development now so fashionable?

In Petrology much attention is now being given to classification, and the aid of the microscope has been invoked to examine into the internal structure of rocks, with results which promise to be of the highest importance, especially in the case of igneous rocks, and those which have undergone structural changes since their deposition. Have we amongst us any Microscopists who will aid and instruct us in this novel and important branch of our science?

How interesting is the enquiry when man first appeared upon this globe, and to trace the evidences he has left of his presence in prehistoric times!

In a mercantile community such as ours, Economic Geology cannot fail to command a large share of attention; and descriptions of those earth products which man has utilised, their mode of occurrence and the means by which they are obtained, and made subservient to our wants, will always prove attractive.

Here is matter enough to choose from to afford us subjects

for papers and discussions for years to come, besides all those the allied sciences of Mineralogy, Physical Geography, Physics and Chemistry offer to us. Is any of the subjects here hurriedly glanced at more attractive than another to any member let him not fear to attach it, but let him write a paper upon it and bring it before us; and thus strengthen and improve both his own and all our knowledge of that particular matter, and the discussion thereon cannot fail to clear and vivify our comprehension. Like the quality of Mercy he will find his attempt to impart knowledge

"Blesseth him that gives and him that takes."

In a local Society local subjects ought to receive a large share of attention, and if any member has a special knowledge of any local matter, let us by all means have his views in a paper, and the benefit of his guidance to the locality.

Excursions for the study of Field Geology will be organised, and I can but express a hope they may be as pleasant and successful as those we have already enjoyed.

It is very desirable that every member who becomes the fortunate possessor of an interesting fossil, mineral or rock specimen, should bring it to a meeting, exhibit and describe it, and a time before the reading of the paper of the evening will always be set apart for this purpose; and for considering any other Communications of Geological facts of interest, which can scarcely be made the subjects of papers.

It is hoped also to form a library of Geological Books, which could be lent out to members and with this object any donations of Books, Maps or Drawings will be most gratefully received.

Arrangements will be made to visit Museums and Collections whenever practicable, and it is anticipated these visits will be largely availed of by the members, and prove alike pleasurable and instructive.

And now let me entreat each member to be animated with an earnest desire to insure the continued success of this

Association. Let each one feel as if the whole responsibility rested on his particular shoulders, and do his utmost to provide us with interesting and instructive matter for our consideration. In all our discussions let our search be after the truth, and however we may differ in our opinions, let us modestly state our views, avoiding all personalities, and guarding our lips, that no word may escape us which may wound the susceptibilities of a brother member, or which we may wish unsaid. Let us work together in the spirit of the good old Cornish maxim,

"ONE AND ALL."

LIVERPOOL GEOLOGICAL ASSOCIATION,

10th January, 1881.

At the Meeting held this date, Mr. Bramall, M. Inst, C.E., President in the Chair, the following were elected as members:—Messrs. T. Mellard Reade, F.G.S., M. Inst, C.E., William Semmons, A. Norman Tate, F.I.C., Herbert Fox, W. H. Miles, J. J. Williams, William Martin, John D. Jones, Isaac Baruchson, J. D. Howard, Mrs. T. Shilston, Miss L. Williams.

Captain H. P. Shilston was proposed as a member.

Abstract of a Paper on—

THE GIANT'S CAUSEWAY,

By Mr. A. Quilliam.

The Geology of Ireland, although not on the whole so varied and complete as that of England, contains however several features of great interest which the "Geologists' Paradise" does not possess. The County of Antrim is in every respect the most interesting part of the Island, because, with a few exceptions, all the formations are represented; there we have the Cambro-silurian, Old Red Sandstone, Carboniferous, New Red Sandstone, Rhætic, Lias, Greensand, Chalk, Eocene, Miocene, and Pliocene, a stronger proof of the mutability of the land it would be difficult to obtain than this small area affords. Antrim also has the honour of possessing the justly celebrated Giant's Causeway, which, according to Prof. Ansted, is the best known example of the columnar structure in Europe, adapted to show the history of the formation. The later sedimentary formations have been preserved by the Miocene lavas, those that are met with are chiefly found along the coast, no doubt laid bare chiefly by marine denudation. At Belfast we have the New Red Sandstone, the Rhætic, the Lias, the Greensand and the Chalk; and also at

Wooburn Glen, two-and-half miles from Carrickfergus, where the Duncrue salt-mines are worked in the Trias. The Lias may be again seen at Barney's Point on the east shore of Larne Lough. At Waterloo, about a mile north of Larne, the Rhætic and Lias are found together between tide marks. Taking the coast road, the Lias is again met with (in the form of a clay), south and north of the village of Glenarm. Quarries are here worked in the iron ore, and plant remains are sometimes obtained from it. At Cushendall the rocks on the shore are a kind of porphyry containing threads of jasper; the other rocks of the district are the Old Red Sandstone and Mica-schist. Further north you reach Ballycastle, where fossiliferous Carboniferous shales are found on the shore. Four miles west of Ballycastle, at Ballintoy, the Lias is once more exposed. In the northeast of the County the Cambro-silurian is developed. Returning to Belfast, at Cave Hill, about a mile from the town, a very fine section may be seen, where a bed of Basalt caps the Chalk, and two dykes have been driven through it, altering it in places. The Basalt in the dykes is foliated along the line of juncture with the Chalk, no doubt brought about by intense pressure. The Chalk is not fossiliferous here, nor indeed anywhere in Antrim. The journey from Belfast to Portrush is rather monotonous, the country being very flat. The only places worth attention are Lough Neagh a lake of Pliocene age, and beds of the same date to the south of the lake; and also Tardree, a village about three miles north of the town of Antrim, where the rare rock Prophyritic Trachyte of Eocene age may be obtained. Before reaching Killigan station, you notice near the "line" a number of mounds that have every appearance of being eskers. On arriving at Portrush (which is a delightful watering place), I went at once to see the celebrated Lias rock that figured in the controversy between the Wernerians and the Huttonians; it is simply a metamorphosed shaley mass altered no doubt by dykes. Portrush is the nearest station to the Giant's Causeway, which is about 8½ miles off. The town is remarkable, as it is built in the midst of a raised Post Glacial beach, which is covered over by sand-

dunes. The raised-beach indicates a very gradual upheaval, and I dont see that there is any reason to believe it is not still going on. Shortly after passing these beaches, the road cuts through a valley in the Chalk overlaid by basalt: the Chalk retains unmistakable evidence of subærial denudation before it was sealed up by the lava. Some distance further ahead the shore and the cliffs are a mass of pure chalk, and several beautiful examples of marine cut arches may be seen. Continuing our journey again, we soon arrived at the famous Dunluce Castle. The descriptions that have been given of its "grandeur" are, I think, much exaggerated; the rock on which it stands is, however, of special interest, as it has taken Geologists thirty-nine years to account for its origin, during which period Portlock, Giekie, and Hull have given their views, the latter two gentlemen contending that the rock was a volcanic neck. However, Messrs. Ramsay, Hull and Traill held council on the spot a few years ago, and they came to the conclusion that it was simply the result of a filled up pipe in the Chalk. The rock, the sides of which are nearly vertical, and 120 feet high, rises from the shore away from the mainland, and it certainly seems remarkable that a pile of fragments (which it in reality is), could have so long withstood the waves; the sea has, however, forced a passage through the centre of the mass, thus giving rise to a cave. The remainder of the route is very dull, and I was not sorry when I reached my journey's end. Passing the hotel on the left, and descending a steep path, you find yourself face to face with the object of your visit,—The Giant's Causeway. Climbing up an isolated cliff west of the structure, you see spread out before you, ornamenting the shore of a beautiful bay, a vast assemblage of columns of every shape and size, artistically arranged in pyramidal, undulating, and horizontal groups. The higher tiers are known respectively as the Little Causeway, the Middle Causeway, and the Great Causeway, which jut into the sea, and are therefore partly covered at high tide. To your right, forming an appropriate background, are cliffs chiefly of amorphous basalt, about 170 feet in height,

and here and there, in the face of the cliffs, are clusters of small columns, twisted and curled in the wildest imaginable fashion; while opposite you see the grand front of the Giant's Organ, no doubt more ornamental than useful. The whole scene is undoubtedly a most impressive one, and I really cannot understand why so many persons are disappointed with it. The Causeways cover several acres of ground, and afford the most striking example of the columnar structure. Each prism looks a distinct piece of workmanship, and fits as closely to its fellows as wax.

"Dark o'er the foam white waves
The Giant's pier the war of tempests braves.
A far, projecting, firm, basaltic way
Of clustering columns, wedged in dense array.
With skill, so like, yet so surpassing art,
With such design so just in every part
That reason pauses, doubtful if it stand
The work of mortal or immortal hand."

Seven-sided columns are plentiful, but five, and six sided prisms are the most numerous. Only one pillar is known with three sides, and only three with nine sides. No two prisms are of the same shape, the majority of the joints are at right, or nearly at right angles to the sides; when a joint is deeply concave the pillar that fits into it is of course convex: many of these abound, and are known as the ball and socket articulations. The prismatic structure has also been met with in Granite, Trachyte, Phonolite, Pitchstone, Felstone, Coal, Volcanic mud and Sandstone: in these masses however the columns are unsymmetrical. The regularity of the basaltic prisms is due to the concave jointing. Columnar forms in igneous rocks result where a very thick and incandescent mass of matter has cooled exceedingly slow; in sedimentary strata it has been brought about by contact with highly heated material. The columns at the lower part of a lava flow are the most regular, because the heat has been very slowly removed by conduction, whereas the surface of the stream is amorphous, the heat being radiated into space, but

lower down small and twisted forms are developed resulting from comparatively slower cooling.

Many very fine sections (especially the Giant's Amphitheatre and Pleaskin Head) are displayed along the coast for miles, of which the Causeway itself is but the lower portion of one of these sections that can be traced from Portmoon Bay, the top having been stripped off by denudation. Which of the denuding agents was it that carried out the work? It is clear that subærial action could not have done so, because the columns have been lifted clean out of their sockets, but as the Causeway is now beyond the reach of the waves, if even they effected the removal of the upper part of the section, it must have been when the whole structure stood at a lower level. Now, at Portrush, a few miles westward, we have indisputable proof of a recent upheaval and it is no stretch of the imagination to suppose that a similiar action went on here. This locality is rich in minerals, but good specimens are, however, rare; the commonest species are Chabazite, Natrolite, Aragonite, Stilbite, Analcime, Agate, Opal and Jasper. A remarkable bed extends along the coast west of the Causeway, known as the "great bole bed." Bole, we are told, is the result of subærial decomposition; this explanation will do very well to interpret a seam a few inches thick; but when we have to account for a seam averaging 25 feet in thickness, it will not apply, because rain would not permit such a large mass to accumulate. Again, in this same bed concentric spheres are found, some of which are over a foot in diameter; it is generally admitted that these spheres result from cooling, so that the matter must at one time have been heated. My conclusion is that the bole was poured out hot from a volcanic cone in the same decomposed condition as we now find it. Like the lavas of Mull these beds have been divided into three stages of eruption by Prof. Hull. The first streams, he states, were trachytic, and belong, probably, to the Eocene. The basaltic rocks, which are of Miocene age, the Prof. divides into two stages; but the data by which he draws the line is not, I think, *clear.* The beds are given as 1100 feet in thickness. Prof.

Judd has shown clearly that these beds are of undoubted subærial origin by the evidence of streams on the underlying Chalk; the presence of beds of unrounded flints; the absence of any marine remains; the vestiges of forest vegetation; and the occurrence of amber, and insect remains. The Antrim lavas are of the same age, and resemble, in every way those of the Inner Hebrides, which Prof. Judd, has so conclusively shown, were poured out by volcanic cones. However, in "Nature," of Nov. 4th, 1880, a short Paper appeared, entitled "The Lava-fields of North Western Europe," by Prof. Geikie, from which it appeared that the author doubted Professor Judd's conclusions; and that he had spent *a day* on the Idaho valley in America, examining a series of igneous rocks and being unable to find volcanic cones he concluded that they had "welled out" of fissures, and as they resembled the Scotch Miocene sheets he contended that they had originated in the same manner. Prof. Geikie states that the "horizontality of the strata and the paucity or absence of volcanic tuffs he has never been able to solve by the ordinary conception of volcanoes with cones and craters." It is, however, the *fluidity* and not the mode of eruption, of the lava, that accounts for the horizontality; for "great overflowing fissures" are in reality a series prolonged cones. At Hawaii we have the greatest volcanic theatre in the world, the lavas being almost as fluid as water. Many eruptions have occurred there within the last 25 years; several of the streams have flowed more than 50 miles, one flood of lava, although it reached a distance of 30 miles the dip was only about one degree. In this island, too, very little fragmentary material is thrown up. It appears to be a general law that when the lava is very fluid little or no fragmental matter is thrown out, and pit-craters are thus formed. I think it is not at all unlikely that the Ulster lavas were poured out of pit-craters, and also that the iron ore deposits accumulated in extinct craters of this description. In the Auvergne district a large number of extinct volcanoes of miocene age are found surrounded by plateaux of lava, unquestionably

brought about by the mobile nature of the material. Reasoning, therefore, by the analogy of active and extinct volcanic action, (especially of the Hawaiian and Auvergne districts, respectively, "for what can we reason but from what we know"), I think there is not the slightest necessity to call to our aid the assistance of unknown phenomena.

LIVERPOOL GEOLOGICAL ASSOCIATION.

7th February, 1881.

At the Meeting held this date, Mr. H. Bramall, M. Inst., C.E., President, in the Chair, Capt. H. P. Shilston was elected a member.

Proposed as members:—Messrs. T. W. Rundell and T. V. Rowlands.

The following Paper was read on—

CURIOUS NATURAL PHENOMENA IN CEPHALÓNIA,

By Capt. H. P. Shilston.

Not far from the town of Argostoli, the capital of the Island Cephalonia, a constant stream, or rather streams of sea water, flow into the land; at present they are conducted through made channels, and utilised for turning water wheels of mills. When first used for this purpose I could not ascertain, only that it was some-time since the island passed under the English rule. The town of Argostoli stands on the S. W. of the island at the head of a gulph about eight miles long; three miles before arriving at the town, a low lying point is passed, the tapering end of a hill composed of altered limestone. On the N.E. of this point stands a mill; proceeding up the harbour another mill is seen distant about three-quarters of a mile from the first; both are worked by the sea water running into the land, losing itself in crevices of the rocks. I had heard of these mills before, and had pictured, from the description, the sea pouring into an open cave, and so turning the wheel. I was rather disappointed to find the water flowing through made channels, and driving the mills by two under-shot wheels; the channels were paved, and the sides lined with boards where the paddles of the wheels work, with about 15 to 18 inches drop only; then, in case of mill No. 1 (on the point),

a rocky pool received the water, which flowed very gently towards two principal crevices in the strata, (that would better describe it than to call them caves), but evidently flowing to these cracks on the side of the pool, rather than through the bottom of the pool where the cracks extended, yet there the water was impeded through loose stones and *debris* that had accumulated therein; this accumulation was always going on, and so all sea weed and such things are carefully kept out, if possible, through loose stones being placed to strain the water, as it were, before it enters the channels leading to the mill wheels. The water from the other mill, after passing under the wheel, was conducted in a channel which branched into two about 200 feet away. One of these ran right towards the hillside, and was lost in a small cavern, apparently losing some of its water as it flowed through cracks in the rocks at its sides. The other stream was lost in a fissure rather than a cavern. These are not the only cracks that the sea flows into; several other fissures along the sides of this promontory let water into the land; the inflow is considerable; these two mill streams are each six inches deep and five feet wide, at the least; so it is rather a puzzle what becomes of the water, or at least, the salt held in solution in the water. The water may pass through capillary attraction, above the sea level even, and be evaporated by the sun; but surely the salt must be accumulating somewhere. All salt beds that I know of have accumulated in the way now going on in the Eastern end of the Caspian sea.

There is a slight Lunar tide all through this part of the Mediterranean sea, and, curiously enough, they say the difference of level is pretty steadily maintained between the water inside and outside the wheels; they have sluice dams, and shut off the water when too high, or not required to work the mills; but they are seldom stopped, even with a low tide, the extremes of which seldom vary as much as two feet. North winds lower the sea level, and S.W. winds raise it, yet tides and winds together do not often exceed this limit.

This Island, and the neighbouring one of Zante, are much subjected to earthquakes, so much so that most houses of two stories high have rents in their walls, from the earth's vibrations; it may be this water has something to do with causing the earthquakes, as all the land around in Greece, the Grecian Archipelago, and into Asia Minor, is of volcanic origin, although no volcanoes now exist nearer than Etna, which is more than 300 miles off.

About two miles to the westward, from mill No. 2, across the arm of the sea, around Lixuri, large quantities of the strata are composed of Gypsum, Gypsum Marls, and soft Clay, with springs containing Sulphate of Magnesia and Carbonate of Magnesia in solution, which get these salts somewhere below, perhaps some from this sea water. Then on the east of the Island there is a strong spring of fresh water out in the sea. This spring I do not think has any connection with [the sea inflow, but the Magnesian springs may. The south part of Cephalonia rises into a mountain 5400 feet high; this of course would be collecting a good deal of water from the atmosphere, but not enough to supply this constant spring, so I suppose it must get its supply from the mainland of Greece, which is not far distant.

Professor Ansted, M.A., F.R.S., who visited the scene of the foregoing Paper, writes of it as follows:

"The fresh water everywhere enters the earth and is always circulating. It not only passes down, into, and amongst, all rocks, but is afterwards lifted, and the level of these subterranean stores is greatly lowered by operations going on at the surface, often at a great distance above. The cause of this evaporation, which proceeds incessantly from the surface of all rocks, but especially from limestones, is the narrow crevices common in limestone rocks acting as capillary tubes. When water falls on the surface of such rocks, it finds its way down readily, and this seems quite natural; but when in hot countries, where there is a long summer season of great drought, the surface becomes dry and hot, moisture rises in steam from below, and as the heat and dryness increase, the accumulated stores become

more and more exhausted. All this goes on without reference to the actual level of the water line within the earth, which may be far beneath the level of the sea. That this is the case in the softer limestone rocks, even when not cracked, has been proved by actual experiment. That it takes place to an enormous extent in the limestones of the Eastern Mediterranean is proved, if in no other way, by the fact that vines planted among bare stones, without soil, obtain an ample supply of moisture from the earth, and ripen their fruit to perfection in in the hottest and driest of seasons. No doubt the earth and rocks are hot, and appear dry; but so long as there remains any water below that has passed down during the rainy season, so long will a part of that water be given back to the dry and thirsty soil above.

"If, then, as is possibly the case, there is so large an evaporation from the part of the Island of Cephalonia, within range of the district, as to keep the water-level of the year below the sea level, in spite of the joint supply of rain and sea water, it is clear that the water may run in for ever, at the same rate without filling up the space. And this, I believe, to be the correct explanation of the phenomena."

LIVERPOOL GEOLOGICAL ASSOCIATION,

7th March, 1881.

At the Meeting held this date, Mr. Bramall, M. Inst, C.E., President, in the Chair, the following were elected as members :—Messrs. T. W. Rundell and T. V. Rowlands.

DONATION.

A Set of the Proceedings of the Liverpool Geological Society.

The following Paper was read—

ANALYSIS OF A SALT FOUND IN A COLLIERY NEAR ST. HELENS.

By Mr. H. T. Mannington.

The Salt was found as an efflorescence on the surface of the Sandstone rock, forming the roof of a gallery in a pit, belonging to the Sankey Brook Colliery Co. at Parr.

On Analysis, it proved to be essentially anhydrous Sulphate of Soda, the figures being :—

80. 8 °/₀ Sulphate of Soda.
17. 0 °/₀ Insol. matter,
Traces of Lime and of Chlorine.

The Insoluble matter is high, being almost entirely Silica, accidentally scraped from the rock. The Lime most probably exists as Sulphate, and the Chlorine as Chloride of Sodium.

Some Water from this pit (analysed some time previously), after concentration in a boiler at the works, shewed grammes, per litre (=parts per 1000) :—

1.42 Sulphate of Soda.
.72 Sulphate of Lime.
.44 Chloride of Sodium.

Sulphate of Soda, in combination with Sulphate of Lime occurs as Glauberite, which consists of about equal parts of each ; also as Mirabilite, a hydrous Sulphate of Soda, containing 10 eq. of Water and as Thenardite which is the anhydrous form. The Salt spoken of would, perhaps, be best designated as Mirabilite which has given up its water.

LIVERPOOL GEOLOGICAL ASSOCIATION.

4th April, 1881.

At the Meeting held this date, Mr. H. Bramall, M. Inst., C.E,. President in the Chair, the following were proposed as members;—Messrs. A. W. Auden and I. E. George.

DONATION.

Abstracts of the Proceedings of the Geological Society of London, Session 1880-1, from Mr. G. H. Morton, F.G.S.

Abstract of a Paper on—

CHANGES OF CLIMATE, "CROLLS THEORY,"

By Mr. Thomas Brennan.

Of all the wonderful things revealed by the study of Geology, perhaps nothing is so surprising to the uninitiated as the evidences of the great changes in climate, which have taken place during past times. That England and the northern portions of Europe and America at one time enjoyed a tropical climate, at another a climate similar to that of Florida, while at a more recent period they suffered from a climate similar to that of Greenland, must seem incredible to those who have not given attention to the evidence upon which the assumption is based.

When it was first announced that an arctic climate had existed in what are now temperate latitudes even Geologists were incredulous, and not for forty years after the evidence was first pointed out by Playfair, were the physical proofs of glacial action, and the occurrence of northern forms as far south as the Pyrenees, allowed their full weight. These are now acknowledged by all Geologists, but great differences of opinion still exist as to the extent, and still more, as to the cause, of changes of climate.

Some, like Professor Judd, are inclined to the belief, that local elevations of the land produced glaciation in these localities; but there is evidence that during a part of what is *termed the glacial* period, a portion of England, and probably

the whole of Scotland and Ireland, were at least 1200 feet below the level of the sea, and conditions which allowed the reindeer and muskdeer to range as far south as the Pyrenees, can hardly be put down as local.

The older Geologists, who knew nothing of the glacial period, believed that the climate of the earth was becoming gradually cooler from the loss by radiation of its internal heat. Sir W. Thompson has, however, shown that the internal heat would cease to affect the surface of the earth before its crust was 10,000 years old.

Lyell maintained that the massing of the land at the poles would give rise to a glacial period. He pointed out the fact that the land stretching away to the north of America deflected the isothermal lines 10° south. He also points out that a similar difference between the eastern and western shores of the Atlantic existed during the glacial period, a fact which seems to tell against his theory. The climate of the miocene period, however, militates very strongly against the theory of Lyell. This period was characterised by a subtropical climate, even to within 9° of the north pole. The land should therefore have been massed at the equator; but so far is this from the fact, that all deposits of this age, in both temperate and arctic regions, indicate shallow seas, lacustrine deposits, or old land surfaces.

A change in the direction of the earth's axis has been called in, to account for changes of climate, but mathematicians hold that such a change is rendered impossible by the protuberance round the equatorial line.

Again, it has been suggested, that a change in the position of the earth's axis might be produced by the removal of a mass of land from one position to another. M. Jules Carot having investigated this theory, has come to the conclusion that an elevation of one-tenth of the earth's surface to the height of 10,000 feet, and a corresponding depression in another place, might, *in the most favorable case*, alter the position of the pole 3° 17". If we imagine the earth to revolve about the new axis and another elevation and

depression similar to the one mentioned above, the change in the position of the poles *might, under favorable circumstances,* be added to the first one, and, by repeating the process, the poles might deviate from their original position 10°. He adds, however, that one deviation might neutralize the other.

Apart from the improbability of the change of figure occurring under the most favorable circumstances, Professor Haughton has shown that the supposed change in the position of the axis will not help us out of the difficulty, as a subtropical flora is found within 800 miles of the supposed position of the north pole during the miocene period.

Two other theories became for a time popular; the first, that our sun is a variable star, with a very long period; the second, that our sun, in his flight through space, carries us into hot and cold portions of it. These theories were short-lived, as it was soon pointed out that heat is as necessary to the production of glaciers as cold is; the ocean might be frozen solid, but no glaciers would be formed. The theory which is most popular at the present day is one propounded by Herschell, but afterwards abandoned by him. Dr. Croll has taken up this discarded theory, and worked it up with great power and enthusiasm, in his book "Climate and Time." Through the precession of the equinoxes the seasons occur in all parts of the earth's orbit. As this orbit is elliptical with the sun in one of the foci, it follows that our winters sometimes occur when the earth is in perihelion or nearest to the sun, and 10,500 years afterwards, when she is in aphelion, or furthest from the sun.

As the earth travels more rapidly when nearing perihelion, it follows that when winter occurs in that part of the orbit, the winter half of the year is shorter than the summer half. At the present time our winters occur in perihelion, and our winter half of the year is seven days shorter than our summer half. In the southern hemisphere the conditions are exactly reversed, the winter half being seven days longer than the summer half of the year.

Again, the shape of the orbit is continually varying; sometimes approaching a circular form, when it is said to have a low eccentricity, and sometimes becoming more elliptical, when it is said to have a high eccentricity.

High eccentricity decreases the perihelion distance, and increases the aphelion distance; this again increases the difference between the summer and winter halves of the year, so that during a period of high eccentricity, the difference may be 36 days. The immediate effect of this would be that we should have a long cold winter and short hot summer in one hemisphere, while we have a long mild summer and short mild winter in the other. Dr. Croll admits that this would not directly produce a glacial period, both hemispheres would receive the same amount of heat, as the shortness of the summer in one case would compensate for the nearer approach to the sun, while the length of the summer would compensate for the increased distance from the sun in the other.

It is upon indirect causes that Croll relies for his glacial period. He argues that during the long cold winters much of the moisture which now falls as rain would come down as snow; that during the short summer a great portion of the sun's heat would be lost in the mechanical work of melting the snow, and some of it would be reflected uselessly into space; that the excessive evaporation would cause dense fogs, and so prevent the sun's rays from reaching the snow. There would, therefore, be an accumulation of snow going on for 10,000 years. Dr. Croll argues that the prevailing winds produce the prevailing ocean currents, and shows very clearly that the direction of winds and currents are identical. He states that the medial line between the N.E., and S.E. trade winds is often 10° north of the equator, and consequently the equatorial current is situated to the north of that line. This he attributes to the semi-glaciation of the southern hemisphere producing stronger winds than the more temperate northern hemisphere. Through the contour of the *land warm* currents are driven into the northern hemisphere. *The gulf stream* is one of the best known examples.

If the northern hemisphere were glaciated, as Dr. Croll believes it would be when our winter occurred in aphelion during a period of high eccentricity, these currents would all be driven to the southern hemisphere, and their place would be taken by the ice cold currents from the north. Under these circumstances Dr. Croll believes that the southern hemisphere would enjoy perpetual spring, while in our latitude life would be impossible.

Croll believes that the massing of the water in the form of ice, round the north pole, would, by altering the earth's centre of gravity, cause England and Scotland to be covered by water, and as the circumstances would vary from one hemisphere to the other every 10,500 years, would give rise to alternate warm and cold climates, and account for the occurrence of southern forms in glacial deposits.

The first and most necessary link in Dr. Croll's chain of indirect causes seems to be open to question.

The experience of Captain Nares is against the indefinite accumulation of ice in high northern or southern latitudes, as very little snow fell in Grinnel Land, the wind being divested of its moisture before it arrived there.* There seems to be a northern and a southern limit to the region of snow, and during a period of high eccentricity this *snow-belt* would probably be further south in winter, and recede further north in summer, than it does at present. For the accumulation of snow it seems necessary to have a gathering ground somewhere to the south of the present snow-belt. Greenland is at present subsiding, and may during the glacial period have extended much further south than at present. It may indeed be the remains of the Continent which is believed by some to have joined Europe and America during the miocene period.

By this modification of Croll's and Lyell's theories the

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*Capt. Nares estimates the amount of snow which fell in 81° N. Latitude from August to May, at 6 to 8 inches, and in Grinnel Land and *North Greenland* the glaciers do not reach the sea. See Capt. Nares *Report.*

difficulties which beset both might be avoided. The supposed continent might moderate the arctic condition when the winter occurred in aphelion, by cutting off the cold currents from the north, as there can be no doubt that ocean currents play an important part in the alterations of climate.

Field Meeting, 18th April, 1881.

Held at Matlock Bath, the Old Nestallo Mine, Cumberland Cavern, Masson, Heights of Abraham, and the High Tor were visited.

LIVERPOOL GEOLOGICAL ASSOCIATION.

2nd May, 1881.

At the Meeting held this date, Mr. H. Bramall, M. Inst., C.E., President in the Chair, the following were elected as members :—Messrs. A. W. Auden and I. E. George.

Proposed as members :—Robt. M. Capon, L.D.S., J. M. Roberts, Granville H. Sharpe, and George Tate, Ph. D.

Abstract of a Paper read on—

"THE RISE AND PROGRESS OF GEOLOGICAL DISCOVERY,"

By Osmund W. Jeffs.

The present is an age of new ideas in all branches of knowledge; on every hand the old makes way for the new. All knowledge is progressive, and it is important that this *Law of Progress*, which is in operation continually throughout the Universe, should be fully recognised, otherwise we are constantly led into error in forming opinions on scientific subjects.

The progress of the Science of Geology has perhaps been more rapid, than that of any other, if we except the Science of Language. Its discoveries have called forth a greater amount of adverse criticism, severe if not always wise, from the superstitious and ignorant, than usually falls to the share of a new Science. Its history possesses, therefore, much interest.

Early Man found in the earth a valuable Storehouse. The various uses made of *Flints*. Advance of civilization taught him the value of minerals, which received special study long before anything was known of Geology.

Earliest References to Geology.—Pythagoras taught, 2,850 years ago, that "the minerals and rocks, islands and continents, rivers and seas, are constantly changing; *there is nothing stationary on Earth.*" Ovid, (" Metamorphoses," Book

XV.) mentions the existence of marine shells lying far from the ocean. Fossils looked upon by ancient philosophers as "figured stones," "freaks of nature."—The origin of many legends can be traced to the discovery of huge fossil bones.

Leonardo di Vinci was the first to comprehend the real nature of fossils and Bernard Palissy maintained their organic character in his work on "Waters and Fountains," (1580.)

Scilla asserted the same in 1670.

In the 18th century, the Italian geologists, Valisneri, Lazzaro Moro and Marselli, established the fact of a regular order of superposition existing in the fossiliferous strata.

The Huttonian Controversy, in the beginning of the present century, excited those who were more eager to form elaborate theories than patiently to investigate facts. The followers of James Hutton, called Plutonists or Huttonians, held that the causes of past changes in the Earth were to be found in existing natural operations; that the original crust of the Earth was Granite, from the denudation of which, together with the production of fresh volcanic matter, all subsequent rocks have been formed.

The disciples of Werner, the Mineralogist of Saxony, called Neptunists or Wernerians, maintained that all rocks, including even Basalt, were of Aqueous origin; that the entire globe was originally covered with water, in which the various materials of the minerals were dissolved, and afterwards precipitated in the order of the existing sedimentary deposits. *Note.*—That Werner ignored all volcanic action.

On the Continent, Buffon showed that veritable sea shells existed on the summit of the Alps, and Cuvier succeeded in reconstructing the entire skeleton of many animals whose bones were discovered in the quarries of Montmartre.

This was followed by a new development of Geological inquiry in England, and the decay of the old school of Mineralogical Geology.

Dr. William Smith, the "Father of English Geology," first grouped rocks according to their fossil contents, and published in 1801 the first Stratigraphical Map of England.

Valuable discoveries of Phillips in the Thames valley and the Palæozoic rocks of Yorkshire. His collection (including Cetiosaurus and other Oolitic Amphibians now in Oxford Museum.)

Dr. Buckland held the Chair of Geology in 1819. Powerful influence of his teaching.

Sir Roderick I. Murchison organised the rocks now known as the "Silurian System." (1835.)

Published "Geology of Russia and the Ural Mountains," 1853, and "Siluria" in 1854.

He also proved the Devonian rocks of Cornwall, to be the equivalents of the old Red Sandstone of Scotland, and established the positions of the Permian formations. He aided the discovery of gold fields in Australia. His energetic support of the Sir John Franklin expedition and the cause of his friend, Dr. Livingstone, in Africa, deserves recognition.

The older slaty strata of north Wales, forming the Cambrian system, were examined in 1836 by Professor Sedgwick.

In 1850, Barrande undertook the Geological Survey of Bohemia, and acquired no less than 1,370 species of fossils. (Trilobites and Cephalopods. *Lyell.*)

Sir W. E. Logan established the existence of the gneissic formations at the base of the Cambrian system, to which the name "Laurentian" has been given. Discovery in these oldest known stratified rocks of the fossil, "Eozoon Canadense."

Note the great contrast between the geological teaching of the present day and that of the beginning of the century. The fancied cataclysms and convulsions of nature of past times when men "tried to explain the unknown by the still more unknown" (*Kingsley*) have given place to a wiser school, headed by Lyell and Ramsay, who show that the agents of change, *now* at work have been guided by the same natural laws ever since the creation of the world, and that past changes in the rocks should be explained by those still going on around us.

At the present time the development of the science is

such that it would be easy to multiply to almost any extent, the names of men who have largely added to Geological research, bnt within the limits of this paper it is quite impossible to give a complete list of even the principal workers.

The important results of the Geological Survey, the labours of Professors Prestwich, Boyd Dawkins, and Mr. Pengelley on Bone Caves; Geikie and Ramsay on the Glacial Epoch; the researches of Huxley and Owen on Palæontology, and those of Sir Charles Lyell on the question of man's age on the earth; the important observations of Dr. Darwin, and the discoveries lately made by Mr. J. Norman Lockyer, relating to the Astronomical portion of the science, all indicate an enlarged sphere of usefulness in store for it.

Thus it happens always in Natural Science: the further we penetrate into its domain, the wider is the prospect opened before us.

Books for reference on the subject:—

Life of Murchison, Sir Roderick Impey, Prof. Geikie, (2 vols,) Principles of Geology, Sir Charles Lyell, Vol I. Chapters 2-4, Geology of England and Wales, Conybeare and Philips; Introductory Manual of Geology, Philips, Chap, I; World before the Deluge, Louis Figuier, translated by H. W. Bristow; Illustrations of the Huttonian Theory, by Playfair, &c., &c.

[The paper concluded with brief Biographical Sketches of Hugh Miller and Robert Dick, the baker of Thurso.

Vide Biographies by Dr. Peter Bayne, (2 vols,) and Mr. Thomas N. Brown, (1858) on Hugh Miller, and by Mr. Samuel Smiles, on Robert Dick, 1 vol, 1879.]

LIVERPOOL GEOLOGICAL ASSOCIATION.

Field Meeting, 6th June, 1881,

Held at Llandudno, conducted by T. Brennan and A. Quilliam. The Boulder Clay deposits at Colwyn Bay were inspected, and the Little Orme was also visited.

13th June, 1881.

At the Meeting held this date, Mr. H. Bramall, M. Inst. C.E., President, in the Chair, the following were elected as members :—George Tate, Ph.D. Granville H.Sharpe, Robert M. Capon, L.D.S. and J. M. Roberts.

Proposed as members :—George O. Chubb and O. H. Elias.

The following Paper was read—

THE HISTORY OF ESCARPMENTS,

By Charles E. Miles.

In the various branches of scientific study the student cannot but admire the brilliant reasoning of those men who also by patient and toiling investigations, have produced such grand results for science. He sees how wonderful secrets deeply hidden have been snatched from the great book of Nature, and the possibilities yet indicated as a further incentive for the untiring investigator. The development of many of these hidden truths has been slow and progressive, the result of the successive labours of different men, and in many cases the foundation of these revelations of science is found in the bold speculations of some thinking mind who has elaborated a theory upon which the experimentalist has built, and the unknown has become the known.

Most people like to theorise a little, but the science of Geology has in time past led to much theorising, and in this

instance, through people accepting fancies instead of enquiring into facts, the science has been much retarded. Geology, is, however, still full of theories, many of which are conflicting, and many serve more to hide a want of knowledge rather than express the reason of facts.

Science has been defined as nothing more than common sense trained, and it is true that common sense has levelled many fine theories which have been replaced by others more reasonable, then some of those theories again have fallen not because they were without foundation, but the observations upon which they were based were too contracted, and have given way to those formed upon wider and more practicable fields of observation. It is owing to these circumstances that the present theory of escarpments is due.

ly Ideas. Previous to the year 1833, it was generally supposed that escarpments, and river valleys owed their origin to fractures in the earth's crust; that escarpments were formed in the first instance by faults, fractures and landslips, and rivers ran through valleys because these valleys were originally fissures, and water naturally runs along cracks. Sir Charles Lyell, in 1833, brought forward the marine theory of denudation, by which it was supposed that the present configuration of hill and valley for the greater part was due to the operation of sea waves in carving them out. This idea replaced the former one of fractures and held great sway until about 1863-5. In Jukes's Manual of Geology, published in 1862 (although his own views had now changed on the subject), you will find it expressed :—

"That taking it for granted that all cliffs at the foot of which the sea is now beating have been produced by the erosive action of its waves, it only requires us to admit that the land may have stood formerly at lower levels so as to allow the sea to flow over the lower parts of it, for us to see the probability that all Inland Cliffs, Scars, Precipices, Valleys and Mountain Passes may have been produced in the same way. * * * Isolated crags and precipices or long lines of cliff and of steep slopes looking down upon broad plains, must have in like manner been formed by the sweeping power of the sea. Broad

open valleys attest a similar origin, and, speaking generally, the principal features in the form of the ground in all lands have been produced by that wide spread action."

Sir Charles Lyell, in 1865, in his Elements of Geology published that year, remarks that—"The geologist cannot fail to recognize in the Chalk hills part of the South Downs the exact likeness of a sea cliff with its succession of capes and coves." That this opinion of the origin of inland cliffs, valleys, &c., due to the operation of sea waves, being held universally for so long is not surprising in one sense, seeing what great power there lies hidden in the form of sea waves; but still it is a matter of some surprise that the true cause was not understood before, as Dr. James Hutton, in 1795, by pointing to actual facts, still in progress, explained the true reason of the formation of river valleys, &c. Professor John Playfair believed that—"there is no part of the land where rivers have not once flowed; that marine currents cannot form valleys gradually increasing in size from the watershed downwards, and that a longitudinal valley consists of two valleys, with their common outlet in a transverse gorge cutting through a ridge;" and Scrope, later on, by pointing to the Auvergne district proved the ability of subærial agencies to perform the work that is now attributed to them.

It was left to British geologists to dissipate the hazy ideas that had grown concerning the power of the sea in producing the present configuration of the land, although in so doing they only reverted to what had been demonstrated by Hutton seventy years before. During the years 1863-4, new light was thrown upon this portion of Physical Geology by the independent observations and writings of Professor Ramsay. Colonel George Greenwood, taking his ideas from Playfair, published, in 1857, his book, entitled "Rain and Rivers"; the second edition following in 1866, which was a great success, maintaining by his Soft Valley and Hard Gorge theory that the valleys of the Wealden area were wholly formed by rain and rivers. In 1862, Professor Jukes, in a Paper read before the Geological Society, London, brought out the

Longitudinal Valley and Transverse Gorge theory (a development of Colonel Greenwood's theory), in regard to the river valleys of the South of Ireland, in which he advocated that they were formed by atmospheric denudation—"as many of the principal rivers of the South of Ireland, after running for miles over low plains, go out of their way to cut through hills." He stated that this theory might be adaptable to the Wealden area. Mr. Wm. Whitaker, F.G.S. and other practical men of the Geological Survey, wrote in the Geological Magazine for 1867, &c., to the same effect, applying Jukes's theory in regard to the South-east of England, and all these writers shewed that the quiet and for the most part unobserved operations of subærial agencies, such as rain, frost, &c., had a much more powerful effect in the carving out of land surfaces than had hitherto been imagined, that in fact the denudation effected by atmospheric influences exceeded greatly that effected by marine denudation. Of course such new theories, or if not quite new, contrary to the prevalent ones, were not accepted by other geologists without some opposition, and while the new subærial theory was upheld by Prof. Ramsay, Col. Greenwood, Dr. Foster, Professor Jukes, Geikie, and others, it was opposed by Sir Roderick I. Murchison, Professor Sedgwick and Philips, Sir Charles Lyell and others, but the opposing school came round to the views of the subærilists, until now few, excepting perhaps some Continental geologists think of contradicting the theory. Mr. D. Mackintosh, F.G.S., has written much in support of the old marine idea, and in 1869, published a book, entitled "The Scenery of England and Wales, wherein his arguments are stated.

It is not the object of this Paper to go into all the questions of the subject of denudation, but to treat of such circumstances that have played the part of producing the cliffs known as escarpments. Escarpments are found in many places, and often form the most conspicuous part of the scenery where they are situated; they are not confined to any particular formation, but are composed of Chalk in one place, Limestone in another, and Sandstone elsewhere. It is in the

South of England where these cliffs have been most studied, and the theory of their development is based upon observations made in that district. We shall now take a glance at the more important ones found in this country, and, after noting their physical appearances, shall proceed from the initial steps in the production of a land surface, to the final operations that have taken place in forming these cliff-like appearances.

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Certainly the most important in point of extent are the escarpments of the Oolites and Chalk. If we go into Gloucestershire we shall notice the escarpment of Inferior Oolite formation called the Cotswold Hills, where in one part it is above 1,100 feet high, these hills form a tableland facing west and overlook a broad plain of Lias Clay and New Red Marl. This Oolitic escarpment runs almost unbroken from Dorsetshire in the South of England northward into Yorkshire, and in great part is over 800 feet high, whilst two points are over 1,000 feet in height. If we travel eastward over the Cotswold Hills, after passing in succession some of the various beds of Oolitic formation cropping out to the surface and forming minor escarpments, we come to another great escarpment, that of the Chalk—covering unconformably the half-denuded Oolites—also facing in a westerly direction, and forming in one part the Chiltern Hills. This escarpment also proceeds from Dorsetshire in a northerly direction as far as the Wash, and again shews its face in Lincolnshire, where it proceeds onward to the north of Flamborough Head in Yorkshire; here it comes to a full stop forming a sea cliff beaten by the waves of the German Ocean. The summit of the Chalk escarpment is very level sloping away very gently fron the scarp. The crest of the scarp is generally about 500 feet high, and rarely exceeds 800 feet. This escarpment forms a bold face overlooking the Vale of Pickering in Yorkshire, and further south overlooks the Vale of York. The highest point of the English Chalk—and also of the South-east of England—is called Inkpen Beacon, 972 feet high, situated where Berkshire, Wiltshire and Hampshire join. The most notable Chalk escarpment in England—notable

as the point upon which all the wordy battles have centred as to the origin of such cliffs—is the one overlooking the Wealden area in the South-east of England. This escarpment we shall have to consider more fully further on. In this area also, in West Surrey, the Lower Greensand escarpment has a crest of from 500 to nearly 1,000 feet high, the summit being Leith Hill, 967 feet high. In Nottinghamshire, Derbyshire and Yorkshire, we have dipping to the east a low escarpment of Magnesian Limestone. In Somersetshire the escarpment of the Lower Lias and Penarth Beds forms the Polden Hills. The Carboniferous rocks have numerous escarpments, both of Mountain Limestone and Grit. A Carboniferous Limestone escarpment overlooks the Vale of Eden in the North-west of England, and we are all familiar with the beautiful escarpments of the same formation that overlook the Vale of Llangollen in North Wales, where this geological feature of this particular formation reaches its culminating point, Fine escarpments are found in the Old Red Sandstone, those of the Beacons of Breconshire being perhaps the most important. Wenlock Edge in Shropshire is a limestone escarpment belonging to the Upper Silurian series.

Physical Features.

We have now to notice the physical features of these peculiar cliffs. Escarpments have been defined by Mr. Whitaker, "as the bounding ridge of a formation or bed, that is to say the ridge along which a formation or bed is cut off, and beyond which it does not extend, except in the form of outliers—it follows the strike." The great point in the foregoing definition is that an escarpment is a cliff that is confined to one formation throughout; it is not like a cliff such as you would find on the sea coast, where the waves have no respect to the strike of the rocks, but cut through them at all angles, thus often exposing the edges of different formations in succession, as, for example, on the East coast of England, coming south from the Tees to Flamborough Head, we meet in the coast cliff first Liassic, then Oolitic, and lastly, Cretaceous rocks. One of the principal features about escarpments is, that they usually consist of hard and

porous beds, lying on softer and more impervious strata; another great feature is that rivers frequently run through them, *i.e.* at right angles to the face of them; in fact the phenomenon is strikingly peculiar to them, as the Severn running through Wenlock Edge. The tops of them are more or less even, and often nearly flat; whilst the base is very uneven, in some parts the base of the cliffs being at a higher level than the tops of the cliffs in other places. They generally form the highest ground of a district overlooking other parts (sea cliffs differing, being backed by higher ground.) They often have springs and water courses at their base, the water courses running parallel with the face of the escarpment. The bases of these cliffs rise to the watershed. Where successive formations crop out, they often run facing the same way in nearly parallel lines for long distances, having plains or valleys between, as those of the Chalk and Lower Greensand in Surrey and Kent, and those of the Chalk and Purbeck and Portland Beds in Dorsetshire. The most striking feature about escarpments is that *whilst the cliff is confined to one particular formation or group of beds along its entire length,* the lower ground at its foot being formed of different beds lower in the order of stratification than itself, *all these beds dip in one direction,* the beds at the foot of the escarpment disappearing beneath those of which the escarpment is composed; the dip being at a moderate angle, a ridge is presented with two slopes, one side of the ridge having a face almost vertical forming the scarp, the other possessing a long gentle slope, which being generally almost identical with the same angle as the dip of the beds, on this account it is called the dip slope. At the base of the scarped face often lie angular fragments of rock, fallen there by the action of the weather from the face of the cliff.

Escarpments frequently have isolated patches of rock with bedding similar to themselves lying at some distance away from their face; these are called "outliers," and shew where the escarpment formerly extended. A good example of this is given by Professor Jukes occuring in the South of Ireland,

where several large detached areas of Coal Measures are found resting in hollows of the beds of Upper Carboniferous Limestone. These beds of Coal Measures are now separated 60 or 80 miles from each other, and usually end in escarpments overlooking the Limestone beds beneath. Several outlying patches of the Coal Measures are often found between two large areas capping the summit of small hills, shewing that the beds were once continuous across. We are thus taught that before these cliffs arrived at their present condition an immense amount of denudation must have ensued to produce them.

Origin. We have now to consider the origin of these cliffs. As before mentioned, it was until about fifteen years ago generally supposed to have been the work of the sea, but any marks the sea may have made upon them would be obliterated after having been exposed so long a time to atmospheric influences. As it is from observations made in the Wealden area that our present knowledge of the subject has been chiefly obtained, we cannot do better than examine that part of the country. The denudation of the Weald of Kent and Sussex has been fully described by Mr. Wm. Topley, F.G.S., in the Memoirs of the Geological Survey Vol., entitled "Geology of the Weald" issued 1875. Prof. Ramsay having made independent observations of the same district, from his description the following is taken:—

Wealden Area. "In the Wealden area we generally find a plain bounded by Lower Greensand and Chalk hills on the north, south and west, while the clayey plain itself surrounds a nucleus of undulating sandy hills in the centre. The whole of this Wealden area forms a great amphitheatre, on the outside rim of which the Chalk rises in bold escarpments, forming what are known as the North and South Downs. On the east it is bounded by the sea* * * This district has a breadth of from 20 to 40 miles from north to south, and nearly 80 from east to west. * * * The result of the denudation of this district is *that great oval* escarpments of Lower Greensand and Chalk

surrounding the Wealden area, rise steeply above the nearest plain which is composed of the Weald Clay, from beneath which the Hastings Sands crop out, forming a central nucleus of hilly ground.* * * The Chalk being comparatively hard has been partly denuded, and now stands out as a bold escarpment in the Downs. The soft clay of the Gault has been more easily worn away and forms a hollow or plain. The Lower Greensand full of hard calcareous bands and ironstone, more strongly resisting denudation, forms a second range of scarped hills overlooking the more easily wasted Weald Clay, which makes a second and broader plain, from which rise the subdivisions of the Hastings Sands, forming the undulations of the central hills of Ashdown Forest, and other places."

The Chalk hills surrounding the Wealden area—especially that winding eastern portion of the North Downs—very much resemble coast cliffs. Speaking of these inland Chalk cliffs in the South of England, Mr. Whitaker has pointed out that "the likeness is not the likeness of a Chalk coast, but is like a coast along rocks of different hardness, the softer yielding to form bays, and the harder resisting to form headlands, and is not like one along a rock of much the same hardness throughout as a Chalk coast would be." Prof. Ramsay shews that if the Wealden area were lowered into the sea just enough to turn the Chalk escarpments into cliffs, we should have two narrow strips of country, one on the south at least 60 and the other on the north not less than 100 miles long, both projecting eastward from the Chalk of Hampshire, the base being at very unequal levels, and forming what we call the North and South Downs. The Eocene strata that skirt them outside on the north and south would be covered by sea, while inside, the scarped cliffs of Chalk would have facing them a series of ridgy islands of Lower Greensand, the centre of the area being occupied by islands formed of the Hastings Sands series. "This form of ground would certainly be peculiar." Prof. Ramsay then points out that *there is an entire absence in the district of superficial marine strata of late date*, the only

superficial deposits upon the outcropping Wealden and Cretaceous series being a deposit of flints near the Chalk escarpments, and the fresh water sands, gravels, and loams of the ancient rivers of the country. Again, excepting near the Downs, *there is an almost entire absence of flints over the Wealden area*, which is a feature of note to be referred to again.

The question arises—how has this area arrived at its present configuration? Not by the effect of fractures in the earth's crust, or even the powerful action of sea waves, but by a series of combined operations extending over a great period of time.

The diagram of a section of the district may assist us for an explanation. If the curvature of the various formations which once extended across the Wealden area, be restored by dotted lines, and then if we imagine these formations planed down to a line running over the tops of the present escarpments, slightly inclined from the centre, we should then have the various beds of Hastings Sands, Weald Clay, Lower Greensand, Gault, Chalk and Upper Greensand cropping up against this line. According to the present theory, this has in reality taken place, the whole of the upper beds as marked by dotted lines have been carried away, planed off in fact by the sea to one level. One of the facts in support of this being the case before mentioned of the absence of flints over the district except in the neighbourhood of the Chalk escarpments. If the Chalk once extended over the district, flints must have been in the strata similar to the present es carpments, and their absence where the Chalk once stood is accounted for on the ground that the sea has entirely removed these beds, forming what is termed a plain of marine denudation—this term being first employed by Prof. Ramsay, in 1847. In producing this plain the work of the sea was here finished, for we know its great denuding force consists simply in its power to attack and bring down cliffs, and where there are no cliffs to attack comparatively little harm is done to the land surface by this agent.

Plain of Marine Denudation. The production of this plain might here be briefly con-

sidered. The average level of the sea breakers forms the line of greatest waste on any coast, above that line, consequently the sea has no power to effect waste, but if the land surface and sea bottom near be very gradually depressed this destruction is greatly assisted, not only by the higher land being brought into closer proximity to the action of the sea breakers, but also by there being more room in the surrounding sea, by its increasing depth, for the distribution of the worn down *débris*. In this way, the interior of the land surface at the same time being eroded by the action of such agencies as rain, running waters, frost, &c., extended over a long period, the two forces working at right angles, a plain of marine denudation would eventually be formed, and, being upheaved, would shew a surface comparatively even. Again, take the reverse case, of land with an uneven surface, or composed of a series of anticlinals, rising slowly out of the sea. On the land being gradually upraised, the tops of these arches would be continually worn down by the action of sea breakers, and the land surface would remain at about the sea level until the upheaving force slowly exceeding that of the denuding force, would give rise to a comparatively even surface above the sea waves. Should the upheaving action be greatest in the centre of the land, this portion of the surface would be higher, and the land would possess a gentle slope towards the sea from the centre. A section of the Limestone rocks in a quarry near Skipton shews such a planing action to have taken place. The central plain of Ireland is stated by Prof. Jukes to be a plain of marine denudation. The rocks below consist chiefly of beds of lower part of Carboniferous Limestone, from which the Coal Measures and upper part of the Carboniferous Limestone have been removed, a general thickness of 2000 or 3000 feet at least being lost, and probably a great deal more than this. Prof. Ramsay quotes an instance in Cardiganshire, observed by himself, where the tops of the Silurian mountains have at one time formed a similar plain. Prof. Jukes mentions the same thing occurring in Ireland in regard to a line drawn from the top of the Knockmealdowns

to the sea the summits of the intervening hills would just touch this line. This peculiarity of the hill tops forming a gently inclined plain has also been noticed by other observers.

In some such manner as described, most probably by the waves acting upon an anticlinal land surface as it rose slowly from the sea, the upper portion of the beds comprising the Wealden area have been denuded, forming a somewhat level plain composed of the out-cropping edges of Hastings Sands, Weald Clay, Greensand, Gault, and Chalk. But a plain composed of these different rocks could not long exist as such when once brought under the influence of atmospheric agencies; these work very unequally upon different rocks. It is not always the hardness of a rock that enables it to resist denudation. Chalk is not by any means a hard rock, yet it resists denudation in a high degree owing to its great property of porosity. After the plain of marine denudation had been completed the Wealden area was upheaved above the sea level, and became subjected to the set of operations performed by subærial agencies, such as rain, running waters, frost, &c.

Relation of Hills to the Dip.

If a land surface has been upheaved from the sea, and the beds lie horizontally, the surface, being everywhere of the same rock, would be lowered equally over the district by subærial agencies, and form a plateau or tableland. If the form of this plateau were destroyed by the action of running waters, the tops of the ridges produced would be of nearly the same height. Should the beds, however, composing a plain of marine denudation dip away from the surface, then subærial agencies, owing to the varying degree of hardness of the various beds, and the varying amount of resistance they each separately offer to the denuding forces, will work unequally upon the land surface, and produce hills of varying height.

We have here to notice that the rivers of the district under consideration do not flow to the sea from west to east, as the appearance of the land would naturally suggest,

and which most probably would have been the case had the sea produced the present surface. In fact some streams rise in the east, close to the sea, and flow westward; but the remarkable feature of the chief rivers of the district is that they mostly flow north and south through the face of the Chalk escarpments. This feature was pointed out in speaking of the physical aspects of escarpments as a great phenomenon, and is common to all such cliffs. The Stour, Medway, Dart, &c., run across the North Downs northward, while the Ouse, Cuckmare, Arun, &c, run through the South Downs to the south.

We shall consider the circumstances that have—according to present ideas—produced this state of things. In the first place, a plain of marine denudation elevated above the sea would not have an exactly level surface, there would be some irregularities by which running water produced by rain would pursue its readiest channel to the sea, and the initial steps for the formation of rivers would be developed. Again, if the upheaving force were exerted more directly in the centre of the area, or along a central axis, a watershed would be formed here from which the rivers would rise, also as the strata would all *dip* away from this axis, the rivers would *flow in the same direction as the dip of the beds*, which is important to notice. It follows therefore that *these first formed rivers would be transverse rivers*—running across the dip. As the land rose higher, the speed and excavating power of the running waters flowing from the central watershed would be greatly augmented, and the rivers would deepen their channels irrespectively of the varying degree of hardness possessed by the various beds over which the water flowed. For instance, a river flowing over beds of Weald Clay, Greensand, Gault and Chalk would flow over beds of varying degree of hardness, and the depth to which the water would cut the rocks would entirely depend upon the rate it cut through the hardest of these beds.

We have now arrived at the theory enunciated by the late Prof. Jukes of the origin of Longitudinal Valleys and *Transverse Gorges* in regard to some of the rivers of the South of

Ireland, being an extension of Col. Greenwood's theory. This extended theory has been adopted to explain the Wealden escarpments, and is embodied in something like the following style of reasoning.

's Theory. As the channels in which water would flow over an upraised plain of marine denudation would follow the slope of the land, and the slope would agree with the general dip of the beds dipping in this case from a central axis, it is plain that the first formed rivers of the Wealden area would be those just mentioned that now run across the escarpments of the Chalk, &c. Rivers flowing across the outcropping strata form valleys which are called on this account Transverse Valleys; but, as you are aware, the form of a valley does not depend for its physical appearance upon the action of the river flowing through it. A river simply cuts a trench in the rocks, and continues to do so until the bed of the river is at about the sea level, the cutting power of the river gradually decreasing in intensity until it reaches this point, when it becomes *nil*. The physical appearance of the banks of a river depends upon the relative hardness of the rocks, and the amount of resistance they offer to the denuding action of rain, frost, and other subærial agencies. Where the rocks are soft over which a river flows, these agencies would produce a wide valley possessing gently sloping banks; but, if, further on, the river flows over hard rocks offering great resistance to the denuding power of these agencies, the valley would here narrow up and form a strait gorge. If this idea be now followed out a little further, it will be perceived, that where the transverse river flows over the outcrop of soft strata, the broadening process just referred to could be continued by each side of the transverse valley, where a soft stratum occurs, being continually eaten into and worn back by subærial agencies at the same time that the transverse valley is deepened. Then, by the action of rain, running water, &c., and consequent washing down of the soft rock into the transverse river, two branch valleys at right angles to the transverse valley would eventually be formed having channels

with streams flowing in them. These valleys being coincident to the outcrop or strike of the soft beds, are, for this reason, called Longitudinal Valleys. Here we have, then, the river of a transverse valley fed by the streams flowing through longitudinal valleys. In the Wealden area the rivers are of this class; the principal which breach the Downs being transverse, while the tributaries of these rivers flow along the outcrop, and are longitudinal. It is often the case, however, that longitudinal streams, though still flowing along the outcrop, have lost the character of tributaries, and, through development, now form part of the main trunk of the transverse river.

A longitudinal stream, like all running water, will deepen its bed as it flows; this deepening into the soft stratum will continue, the banks at the same time becoming wider through subærial agencies, until the stream has reached a hard bed underlying it. Here circumstances are altered, and a change takes place in the direction of the energies of the stream. As running water pursues its course where it finds the readiest channel, it is obvious that the energies of the stream are not now exerted in a vertical direction entirely, as there they meet with more resistance in the harder rock beneath, the stream therefore attacks the banks of soft rock on either side, but as the soft bed lies on an inclined plane of hard rock, the stream follows this plane as it eats into that bank of the easily denuded material which covers the declivity of the hard bed. Hence this bank is constantly getting undermined and carried away by the longitudinal stream, the upper part of the bank being simultaneously worn down by atmospheric influences. In this manner the longitudinal river or stream working both vertically and laterally, removes the soft bed in descending the slope of the hard bed beneath. This erosion of the bank is continued until at length the outcropping surface of the next hard bed is reached. The stream will then have arrived at a point where, flowing over a hard bed, it is flanked on one side with a gently sloping bank of soft rock capped by another hard bed, this bed shewing a

steep face overlooking the valley beneath. Thus an escarpment is formed. In the meantime the bank on the opposite side of the valley has also been acted upon by rain, &c. and more or less removed, the *débris* being washed into and carried off by the longitudinal stream. Eventually we see produced in the outcrop of the soft stratum a wide valley or plain, overlooked on one side by the steep face of an escarpment of hard rock, at the base of which a bank of soft rock comes sloping gently down, and thus the Wealden escarpments are accounted for.

Here we have at length, as far as the teaching of the rocks of the South-east of England and other places serve us, arrived at the origin of escarpments, and a short *resumé* of the whole theory would perhaps not be out of place.

Summary of Theory of Origin. In the first instance a sea bottom has been slowly upraised. The upheaving force being more powerfully exerted along a central axis of the area, the rocks would form a long gentle anticlinal, the beds dipping away on each side. As the land rose slowly upwards, the sea breakers would batter down the surface of the anticlinal and form a plain of marine denudation. The land, rising above the sea, would become exposed to the action of a set of operations performed by subærial agencies which work unequally on different rocks, some rocks being hard or possessing other properties resisting their denuding power, while others are readily acted upon and eroded. Owing to the beds composing the upraised plain forming an angle to the horizon, and the surface of the plain having a gentle slope following in the same direction, the first formed rivers of the area would follow the slope, and hence flow transversely across tbe outcrop of the beds. On this account they are called Transverse Rivers, and would be the principal ones of the district. Meanwhile as the plain is made up of rocks varying in hardness, the ever hungering powers of the atmosphere would eat into the outcropping soft beds where they formed the banks of transverse rivers, and *produce streams* along the strike of the soft beds. These *are called* longitudinal rivers or streams, and would act as

feeders to the transverse ones. A longitudinal stream, by working down until it reached a hard bed beneath, and then following the slope of this bed as it eat into the bank covering it, aided by rain, frost, &c., in removing the banks, would eventually carry off most of the soft bed from above the hard one, until the bank worn by the stream reached the outcropping surface of the next hard bed. Here an escarpment would be formed with all its peculiar and striking characteristics, overlooking a valley or flat plain.

Escarpments when formed do not remain stationary, they recede by the action of subærial agencies. The soft bed beneath the face of the scarp being eroded by these agencies, the hard bed is undermined, and often falls away in blocks, and the valley overlooked by the escarpment is accordingly extended.

Although what has been given as the primary causes in the production of these cliffs, they are not all formed in such a cut-and-dried manner as described, and there often have been many modifying influences at work to obscure the origin of their development, which otherwise would be palpable. Then from what has been stated as the way in which streams help to form these cliffs, they must not be confounded with river cliffs which are produced in a different manner. The rivers running parallel to the face of escarpments being usually found at some distance in front of them, where they may be often observed cutting into the soft bank above which slopes gently from the scarp, Again, all hills possessing scarped faces are not escarpments. At Thurstaston we have a hill that in some respects resembles an escarpment. On the western and southern slopes several scarped faces are to be seen rising in tiers. The hill according to the Survey map is Upper Bunter, a hard bed occurring overlying the top. On the western slope the undermining of this hard bed can be seen in progress, large blocks may be noticed on the hillside that have fallen away from it. An escarpment, however, is inferred to be due to subærial agencies, and in this respect the hill differs, the origin evidently

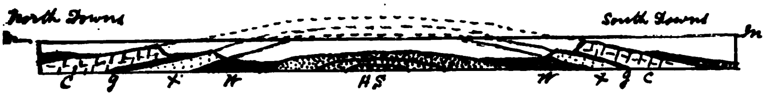
being due to faults, as the hill is completely intersected by faults crossing each other at nearly right angles, which have tilted the beds into their present position. One effect of this disturbance having been the production of that remarkable huge block of sandstone on the eastern slope—now considerably modified by human labour—called Thors Stone. Not very far from Liverpool we have the Peckforton Hills, some parts of which are about 1000 feet high. This range appears as a table-land presenting a steep escarpment facing west, the outcropping edges of hard Lower Keuper Basement beds, &c., forming the face. The hill upon which Beeston Castle stands is an outlier of this range. The escarpment theory may perhaps be applied here, but then it is a question as to what extent faults have contributed to the present configuration of the surface. At the southern extremity of the estuary of the Mersey we have a range of hills which at Helsby presents a bold cliff face of Lower Keuper Basement beds, the summit here being 472 feet above the sea level. This cliff overlooks a flat plain extending to the Mersey, and in some respects resembles an escarpment, but it also much more resembles the appearance of an old river cliff.

The question of the probable age of the principal escarpments of the country is a very interesting one to study, but cannot be dealt with in this Paper, as the limits originally intended have been exceeded—the object of the Paper being the putting together of a few facts and theories which, although covering old and well trodden ground, yet indicate in the history of escarpments the keynote of the great subject of subærial denudation, in which something new can always be found by those who take pleasure in a study of the rocks.

BOOKS REFERRED TO ON THE SUBJECT.

Quart. Jour., Geol. Soc., Vol. 18, Paper by J. B. Jukes, on the River Valleys of the South of Ireland: Quart. Jour. Geol. Soc., Vol. 21, Papers by Dr. Foster and Mr. Topley; Geol. Mag., Vols. 3 & 4., Papers on Denudation, by Whitaker, Jukes, Topley, Mackintosh, &c.; Physical Geology and Geog. of Great Britain, Prof. Ramsay; Rain and Rivers, Colonel George Greenwood, 1866; Student's Manual of Geology, Prof. J. B. Jukes, 1862; and Ditto, edited by A. Geikie, 1872; Geology of England and Wales, H. B. Woodward, F.G.S.; The Scenery of England and Wales, D. Mackintosh, F.G.S.; Geology for Students, A. H. Green; *Huttonian Theory*, Playfair, 1822; Scenery of Scotland, Geikie, 1865.

Section across the Wealden Area, exaggerated in height

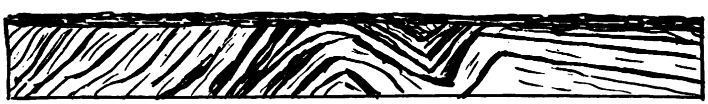


C.C Chalk & Up Greensand Escarpments forming Nth. & Sth. Downs
g.g Gault generally forming a plain
X.X. Escarpments of Lower Greensand
W.W. Weald Clay generally forming a plain
HS Central hills of Hastings Sand
M.M. Plain of marine Denudation. Dotted lines shewing former extension of beds across the district.

From Ramsay's Book

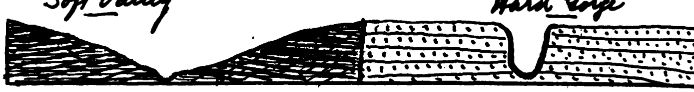
Hill tops in Cardiganshire representing Old Marine Plain of Denudation

Section in limestone quarry near Skipton
Contorted strata, the tops of the anticlinals shewing Marine Plain



Soft Valley

Hard Gorge

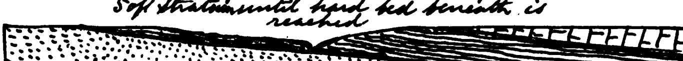


Ideal transverse section across inclined beds illustrating the development of escarpments

Plain of Marine Denudation

Formation of Longitudinal River in the outcrop of Soft Stratum

Descent of Longitudinal River through the Soft Stratum until hard bed beneath is reached



Formation of Escarpment overlooking Valley in Plain

LIVERPOOL GEOLOGICAL ASSOCIATION.

Field Meeting, 2nd July, 1881.

Held at Storeton Quarries, Dr. C. Ricketts, F.G.S., led the party over the quarries, and drew attention to the vertical striations possessed by the slickensides of the north and south faults, the striæ on the slickensides of the east and west faults being diagonal. The footprint bed in situ was observed.

4th July, 1881.

At the Meeting held this date, Mr. H. Bramall, M. Inst. C.E., President, in the Chair, George O. Chubb and O. H. Elias, were elected as members.

Proposed as members :—H. T. Roberts, T. G. Williams and Miss M. Owen.

The following Paper was read—

NOTES ON THE BRIXHAM BONE CAVES,

By Thomas Shilston.

Bone caves always occur in limestone strata, those of England being found in the Devonian, Carboniferous and Permian formations. Professor Ramsay says that in Britain at least 86 caves have been recorded as holding the remains of terrestrial Mammalia, and, doubtless, the list will be largely increased.

Most limestone rocks are jointed, through these joints rain water percolates, and holding as it does carbonic acid in solution, which it has obtained on its passage through the air as rain, dissolves by degrees part of the limestone, which it carries away in solution in the form of bi-carbonate of lime. A passage for this water being once formed, the opening through which it flows will be continually increasing in size, and you have only to allow this constant flow and time enough to form a cavern of any required size.

The Brixham Cave situated in Devonshire was discovered in 1858, and on my visit in June, 1880, the proprietor described the occurrence thus:—He was excavating the side of the hill to lay the foundations of some cottages he intended to build, and while so doing was suddenly precipitated through the roof of the cavern, a distance of five or six feet, alighting on the stalagmite floor. On an investigation, the cave so unceremoniously entered was discovered to be of some considerable extent, but what increased the interest was the discovery of a large reindeer's horn slightly imbedded in the stalagmite floor.

The news of the discovery soon spread, and arrangements were made by the Geological Society for a thorough and scientific exploration, which commenced 14th July, 1858, and from a report dated 9th September of the same year, it appears to have settled a point of much interest at that time, viz., the super position of undoubted remains of the Reindeer above that of flint knives bearing evidence of human workmanship, from which the inference arises, that the Reindeer continued to be an inhabitant of Britain after the appearance of man. The exploration was completed in the summer of 1859, the whole cavern was found to be comprised within a space measuring 135 feet from north to south, and 100 feet from east to west. The galleries, which measure 6 to 8 feet in greatest width, and from 10 to 14 feet in height, resolve themselves into two sets or systems, having the same bearings as the joints of the Devonian rocks of the district, the joint generally being well marked in the roofs of the several galleries.

The walls are very irregular, the edges have been rounded off, and possess a rough polish, evidently the result of flowing water, this fact is further made clear by two deep grooves having been worn in the side walls throughout the entire length of the galleries. These grooves are seen at corresponding levels on each side, and have a gentle dip towards the present entrance.

A floor of stalagmite, of a pure white or cream color,

sealed up in a most effectual manner the remaining contents of the cave, it was in thickness from a few inches to one foot. In this floor itself 25 bones were found. In the deposits below were found 1596 bones and 36 flints. These deposits consisted mainly of a "reddish brown tenacious clayey loam." The lowest deposit of all contained pebbles of "quartz, greenstone, grit and limestone mixed with small fragments of shale, also a few pieces of sandstone."

The following animals are represented among the bones found—viz., Mammoth, Rhinoceros, Horse, Ox, Reindeer, Cave Hyæna, Brown Bear, Grisly Bear, Roebuck, Cave Lion, Fox, Hare, and Lemming—the bones of the Bear being by far the most numerous. On some of the bones were found the teeth marks of the animals by which they had been gnawed.

The flints found were submitted to Mr. Evans, and on them he reports as follows :—

"They have (he says) for the most part, undergone great alteration in their structure, having become white, absorbent, and brittle, and, in the case of the thinner flakes, throughout their entire substance, and in the larger pieces to a considerable depth from the surface, if not, as appears to be the case with the largest of all throughout. Though much softened in texture, the surface retains in some instances a bright porcellaneous glaze. On several there are portions left of the original surface of the flint, which appears to have been derived from the chalk. In one instance this original structure is much battered as if the block of flint had been exposed for some time on the sea shore before it was picked up to be utilized by man."

Mr. Evans thus describes one flint, and it may represent his description of the remainder. No. 5 in Mr. Pengelly's List. "Broad ended flake $2^3/_4$ in. long, the ridge formed of two facets with a third transverse facet at the broad end. This flake has been chipped or jagged along one edge, apparently by use, while the broad rounded end is much worn away, in all probability by scraping some hard material. These

evidences of this extremely simple instrument having been designedly formed, and of its having been employed for cutting or scraping purposes, are most clear and satisfactory."

It is evident that the cave served for a very long period as a passage for water, though there is reason to believe that all the bones were not brought in by water, but a proportion of them by beasts of prey, such as the Hyæna, Lion, and Bear, the bones of the latter animal being found in such quantity and in such condition as to lead to the inference that when the cave was dry it was used by them as a den. The area of drainage of the district is so small, and the rocks so impermeable, that the stream must have been occasionally dry, and at such periods, probably, were the remains of the Mammoth, Horse, Ox, &c., brought in at intervals by the Lions and Hyænas and devoured on the spot, for the bones shew little trace of wear and much of gnawing. We may also suppose that during periods of drought the skeletons of animals having died would become weathered, and perhaps moss-grown in the bed of the stream, which, when again swollen by rain, would carry them into the cave. Judging from the position in which the bones were found, it has been thought that "as the deposit of the cave earth proceeded a change appears to have gone on in the animals frequenting the district, or else owing to the cave having become gradually drier, and less subject to flooding. The remains of Elephant, Rhinoceros, and Cave Lion gradually disappear, those of Hyæna become less common, whilst the Bears increase greatly in numbers. This animal seems to have made it a place of habitual resort, and to have taken possession of the more retired parts of the cave. Instead of detached bones, numbers of bones of Bears, including those of very young, merely sucking cubs, were found together, leading to the inference that they were the remains of animals which died or were killed on the spot, or drowned where they were found by the flooding of a stream which flowed at a lower level, and as they were neither gnawed nor dispersed, it may be inferred that the Hyæna had ultimately ceased to frequent the cave."

There does not appear to have been any evidence found, pointing to the cave ever having been used as a place of habitation by man, therefore the presence of worked flints may be due to their having been left behind or lost by man during occasional visits for temporary shelter, or in the pursuit of wild animals.

Having thus gone through the salient points of the able and complete record of the exploration of this cave, presented to the Royal Society, accompanied by my own impressions from a recent visit to the spot, I would only in conclusion note the thought which occurred to me, as I stood on its site, and that was, the enlargement of grasp required to entertain the idea of time needed for Geological work: to imagine the little insignificant stream, which could be stepped across, and draining so limited an area, as capable of hollowing out the considerable valley before one, required conclusive evidence to satisfy, and that evidence the Brixham Cave abundantly supplied. I quite agree with the Rev. J. Symonds, F.G.S., in his conclusions on this subject, that the following series of changes must have happened.

1st.—The valley has been eroded to a depth of about 100 feet *since* the deposition of the cave relics.

2nd.—After its excavation was completed it was partially filled with a deposition of loam.

3rd.—On this loam in the neighbourhood grew the trees of the submerged forest period.

And 4th.—Since the forest period the entire country has lowered to the extent of about 40 feet.

LIVERPOOL GEOLOGICAL ASSOCIATION.

Field Meeting, 1st August, 1881.

Held at the Wrekin, Shropshire. The gravel-pit in Ercal Hill was first visited, where an intrusive Rhyolitie is to be observed. The quarry in Lawrence Hill was then proceeded to, where altered Basaltic dykes are to be seen intrusive into beds of highly indurated volcanic ash. The bare mass of Dolerite in theWrekin supposed to be an old volcanic vent was noticed, and also the banded lavas at the summit. Notes of the Geology of the district were prepared by C. E. Miles to explain the sections exposed, and these notes slightly extended are subjoined for future reference.

The Wrekin Group.

Ercal Hill, Lawrence Hill, The Wrekin, Primrose Hill.

In the gravel-pit of Ercal Hill a red Granitoid rock occurs dipping to the south. At the bottom part of the mass there are indications of a clastic origin, but this appearance may perhaps be due to another cause, that of the intrusive Rhyolite. The Quartz of this red rock contains numerous minute enclosures. *Underlying* the red rock, is found a compact greenish-white bed, containing fragments of a red rock resembling the granitoid mass. Prof. T. G. Bonney describes the underlying bed as a mass of Wrekin Rhyolite intrusive in the granitoid rock, the latter he believes to be considerably older than the intrusive mass. This intrusive mass has a rather brecciated structure, and a more or less glassy texture, exhibiting fluidal arrangement and the usual aspect of a devitrified glass.

Lawrence Hill is a portion of the Wrekin ridge, formed by the ridge being cut through at right angles by two deep and narrow gorges. A large quarry exists at the south of the hill where thick beds of highly indurated Volcanic Ash are seen dipping in a northerly direction at an angle of 50°. These

beds are covered by masses of altered Pitchstones and Felsites, well exposed on the south slope of the hill, on its northern face, and also on the opposite crags of Ercal Hill. Two dykes, one 12 feet and the other 14 feet wide of highly altered Basalt occur in the quarry, Calcite being deposited in the cracks, the ash beds in contact with the dykes being much altered. These dykes strike towards a mass of Dolerite in the Wrekin. On the S.E. side the ridge is flanked with Quartzite, succeeded by Hollybush Sandstone and Shineton Shales.

On the side of the Wrekin opposite the quarry in Lawrence Hill, Tuff beds are exposed, similar to those of Lawrence Hill. Near the Cottage on the Wrekin the tuff is a Breccia, sometimes conglomeratic, the pebbles consisting of felstone, pitchstone, and less frequently, quartz. About midway on the Wrekin from N.E. end to the summit is found a bare hump of dark green Dolerite in some parts agglomeratic, in others amygdoloidal with nuclei of calcite. Several vertical dykes proceed from this boss, the boss appearing to have been an ancient volcanic vent. Following the ridge to the S.W. there occurs a reddish Felstone, in places banded into laminæ of various colours, alternations of dark chocolate with buff bands being common. Near the summit these Pre-Cambrian lavas are underlain by a greyish Agglomerate, having a northerly dip. At the summit is found reddish and chocolate colored Felstone. In the saddle between the Wrekin and Primrose Hill underlying a compact red felsitic rock occurs typical Agglomerate.

On the S.W. slope of Primrose Hill about twenty yards below the top, crops out a band of Schistose rock dipping to the N.E. at 55°. It is a very quartzose Granulite, the quartz being sometimes quartzite and the felspar like the red variety in the Ercal quarry. A red rock appearing to be identical with the granitoid rock of Ercal Hill is also found here.

Prof. Bonney states that the Quartzite of the Wrekin consists of well rounded quartz grains, pretty full of very minute enclosures, and bear a strong resemblance to the quartz of the granitoid rock. The binding quartz is free from enclosures. Fragments of a rather decomposed rhyolitic rock are also mingled in the Quartzite.

THE WREKIN AND ITS DISTRICT.

The Wrekin has been described by Sir R. I. Murchison as of Caradoc age, an igneous outburst altering the Caradoc Sandstone on its flanks to Quartzite. Dr. C. Callaway, F.G.S., has lately given reasons before the Geological Society, shewing that the Wrekin is an old Pre-Cambrian volcanic bedded deposit, upon which lie, unconformably, altered Pre-Cambrian or Cambrian Sandstone, after the deposition of which a later volcanic outburst has occurred.

The Wrekin is about 1,320 feet above the sea level. The ridge lies in a N.E. to S.W. direction for about three miles, being a quarter of a mile at its greatest breadth, the strike of the beds being about east and west. The lavas and tuffs dip to the north, at about 45°. Upon Pre-Cambrian bedded lavas and ash beds lie unconformably flanking each side of the ridge altered Lower or Pre-Cambrian Sandstone, (Quartzite) about 200 feet thick, this Quartzite also laps round the ends, and dips from the central mass at an average of 45°, the base being brecciated. On the north-west side, the Wrekin is bounded by a fault separating it from the Bunter. On the south-east the Quartzite is succeeded by a series of thin bedded micaceous green Sandstones, which Dr. Callaway has shewn to be identical with the Hollybush Sandstone (at least Upper Cambrian) of the Malvern Hills, containing the fossil **Kutorgina cingulata* (Brachiopod); outside of this is a parallel zone of dark blue, and micaceous Shales, termed by Dr. Callaway the †Shineton Shales, and which are correlated by him with the Dictyonema Shales of the Malvern Hills. The junctures of the Quartzite, Hollybush Sandstone, and Shineton Shales are parallel lines of fault.

The Shineton Shales underlie the May Hill Sandstone unconformably; they underlie the Caradoc, but are not clearly found *overlying* any formation.

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*At Neves Castle, S.W. of the Wrekin, are two quarries; in the one to the south of the road these fossils are found in abundance.

†Near Shineton about two miles south of Neves Castle, two good sections are exposed on the left bank of the stream, marked on the Survey map with an arrow dipping to the S.E. at 50. Cambrian fossils, Trilobites, &c, can be found here.

In the neighbourhood to the south and south-west of the Wrekin are found—

May Hill Sandstone—Upper Llandovery of Murchison, (Lowest beds of Upper Silurian)

—lying unconformably upon beds beneath by change of dip.

Chatwall Sandstone... Harnage Shales ...... Hoar Edge Grits......	Caradoc — Upper Cambrian of Sedgwick and Lower Silurian of Murchison.
Shirreton Shales	Probably may be beds of passage between Lingula-flags and Lower Tremadoc.
Hollybush Sandstone Quartzite	

Extending parallel to the Wrekin ridge, but separated by a distance of from half-a-mile to a mile, lie the remains of a succession of bands of Basalt and Volcanic Ash, the latter being studded with innumerable Volcanic Bombs—seen near Little Wenlock. At Harris Coppice is another ash bed, containing small grains and lapilli, with a bed of Basalt resting upon it, and both overlaid by Millstone Grit. This eruption being subsequent to the Wrekin lavas, and presumably emitted from the volcanic vent in the Wrekin.—Described by Dr. C. Ricketts, F.G.S.

Vide.—Transactions of the Geological Society of London, Vols. 33 and 35; Papers by Dr. C. Callaway, F.G.S., and S. Allport, F.G.S., with notes by Prof. Bonney; from whose descriptions the foregoing notes on the subject have principally been taken.

LIVERPOOL GEOLOGICAL ASSOCIATION.

August 8th, 1881.

At the ordinary Meeting held this date, Mr. H. Bramall M. Inst., C.E., President, in the Chair, the following were elected as members :—

Miss M. Owen, Messrs. T. G. Williams, and Hugh T. Roberts.

The following Paper was read :—

ISOMORPHISM AND DIMORPHISM,

AS ILLUSTATED BY MINERAL SPECIES,

BY GEORGE TATE, PH. D., F.G.S.

Mineralogy viewed merely as a classificatory science or determinatory art, is essentially a branch of Descriptive Chemistry. The phenomena of isomorphism and heteromorphism, and more especially those of pseudomorphism, as being a key to the changes of minerals and mineral matter that are now taking place, and to which they have in the course of long ages been subjected, are of highest interest to the philosophical chemist, and of value to his speculative science.

The otherwise unattractive subject of Mineralogy, when it treats of and investigates these subjects, becomes one of the most fascinating and important branches of chemical and geological science.

The first accurate observations and experiments on Isomorphism were those made by Mitscherlich, in 1819, on the hydrous phosphates and arseniates, and the sulphates, *manganates and* chromates.

The law was enunciated by him, in effect, in the following terms :—"*Similarly constituted bodies crystallized in similar or closely allied forms,*" or "*Analagous elements or groups of elements may replace one another in compounds without essential alteration of crystalline form.*"

I will at once add that the law is far from possessing general truth.

I will explain — firstly, what is meant by the term "similar constitution" in the idea of the chemical atomic molecular theory, and then in the course of my paper give the more remarkable instances of isomorphism among minerals, among the oxides, the carbonates, sulphates, sulphides, phosphates, and silicates, pointing out cases of heteromorphism (that is where the same chemical body crystallizes in more than one form) and finally show the great aid this law of isomorphism gives the chemist in the determination of the atomic weights of the elements: for, since this branch of physical chemistry is being ever more and more wrought out by chemical and mineralogical investigators, it is essential that all mineralogists should follow and appreciate the value of these researches.

* * * * *

The author then gave an outline of Dalton's Atomic theory and the doctrine of Quantivalence.

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All crystal forms are reduced to systems of which it is usual to suppose six. These are distinguished by their differences of symmetry, and the crystal planes are all referred to certain axes to which the planes of symmetry have a fixed relation, and all forms are derived from simple primary forms. The primary forms in the cubic or tesseral system are the only ones which are, for all species of minerals crystallizing in that system, the same; therefore only in the cubic system can isomorphous bodies crystallize in the *same* form, in the other systems the forms can only be *similar*.

Therefore my first case of isomorphism will be taken *from the regular* system, and is that of the Spinel group, all

members of which usually occur in octahedrons. These minerals are compounds of a protoxide of the general formula $M''O$ with a sesquioxide $M_2'''O_3$ where MO can be FeO. MnO. MgO. ZnO. &c., and M_2O_3 can be Fe_2O_3, Cr_2O_3, Al_2O_3, &c. *Spinel* itself is a compound of MgO (magnesium oxide) with aluminium oxide Al^2O_3; its formula is MgO. Al_2O_3.

The isomorphic relations are exemplified by the following table :—

General Formula	$M''O$. $M_2'''O_3$.
Spinel	MgO. Al_2O_3.
Magnetic Iron Ore	FeO. Fe_2O_3.
Pleonast	(MgFe) O. $(AlFe)_2O_3$.
Chlorospinel	MgO. $(AlFe)_2O_3$.
Automalite	(ZnFe) O. $(AlFe)_2O_3$.
Picotite	(MgFe) O. $(AlCr)_2O_3$.
Franklinite	(ZnFeMn) O. $(FeMn)_2O_3$.
Chrome Iron Ore	(FeMgCr)O.$(CrAl)_2O_3$.

Here the composition of all these minerals is reduced to the general formula $MO.M_2O_3$.; where the metallic symbols are enclosed in parentheses it implies that the metals are capable of isomorphically replacing each other. This example shows the isomorphism of Magnesium Oxide (MgO), Protoxide of Iron (FeO), Zinc Oxide (ZnO), Protoxide of Manganese (MnO), and Protoxide of Chromium (CrO) and of the sesquioxides, Alumina (Al^2O^3), Peroxide of Iron (Fe^2O^3), Sesquioxide of Chromium (Cr_2O_3), and Sesquioxide of Manganese (Mn^2O^3).

The carbonates offer a very interesting case of isomorphism as well as of heteromorphism. These carbonates possess the general formula MCO_3; they crystallize in the Hexagonal, Rhombic, and in one instance in the Oblique or Monoklinic systems.

Composition.	Hexagonal Mineral	$R:R$.	Rhombic Mineral	$\infty P:\infty P$.	Oblique Mineral.
$CaCO_3$.	Calcite	105°.5′	Arragonite	63°.44′	
$MgCO^3$	Magnesite	107°.25′			
$\left.\begin{matrix}Ca\\Mg\end{matrix}\right\} CO_3$	Dolomite	106°.15′			
$FeCO_3$	Spathic Iron	107°0′			
$MnCO_3$	Diallogite	106°.51′			
$ZnCO_3$	Calamine	107°.40′			
$\left.\begin{matrix}Mg\\Fe\end{matrix}\right\} CO_3$	Breumierite	107°30′			
$BaCO_3$			Witherite	61°.30′	
$SrCO_3$			Strontianite	62°.44′	
$PbCO^3$			Cerusite	62°.46′	
$\left.\begin{matrix}Pb\\Ca\end{matrix}\right\} CO_3$	Plumbocalcite				
$\left.\begin{matrix}Ba\\Ca\end{matrix}\right\} CO^3$			Alstonite	61°.10′	Baryto-calcit

Plumbo calcite indicates the isomorphism (and cerusite the dimorphism) of Lead carbonate with Calcite; Plumbocalcite being an isomorphous mixture of Calcite with an unknown Hexagonal Lead carbonate. Barytocalcite in the same way indicates the existence of a Calcium carbonate crystallizing in the oblique system isomorphous with a similarly unknown oblique Barium carbonate.

All these minerals are similarly constituted, and those of the respective groups crystallize in similar forms, the divergence from exact equality being indicated by the angles between the planes of the primary forms indicated at the head of the columns.

In the Sulphates interesting instances occur:—*Anhydrite* ($CaSO_4$), *Heavy Spar* ($BaSO_4$), *Cælestine* ($SrSO^4$) and *Anglesite* ($PbSO^4$) are all isomorphous.

In all the cases I have yet cited where this law is illustrated there have been similarly constituted bases that possess the replacing power.

In the instances I will now give we see that acidulous radicles or elements also exhibit isomorphic and heteromorphic relations.

For instance among the arsenides and sulphides, some crystallize in the regular system (e.g. Iron pyrites FeS_2 and Smaltine $Co\ As_2$) and, forming a parallel series dimorphic with these, there occur disulphides and diarsenides of the Rhombic system. *

Among the arseniates and phosphates isomorphism is common, thus the hydrous arseniate of Iron Skorodite corresponds to the similarly constituted phosphate *Strengite*; *Olivenite* corresponds to *Libethenite*.

But the most interesting case in these salts is that in the Apatite group :—

HEXAGONAL.	COMPOSITION.	P:P.
Pyromorphite	$Pb_{10}P^6O_{24}Cl^2$	80°.44′
Apatite	$Ca_{10}P^6O_{24}Cl_2$	80°.26′
Mimetesite	$Pb_{10}As^6O_{24}Cl^2$	81°.48′
Vanadinite	$Pb_{10}V^6O_{24}Cl^2$	78°.46′
Hedyphane	$(Pb\ Ca)_{10}(As\ P)_6O_{24}Cl_2$	

The similarly constituted chloro-arseniates, phosphates, and vanadinate of Lead and Calcium possess essentially the same form; *Hedyphane* may be regarded as an isomorphous mixture of *Mimetite* and *Apatite*. The Chlorine in Apatite is frequently replaced by Fluorine. By this example is thus shown the isomorphism of Lead and Calcium, Phosphorus, Arsenic and Vanadium and of Chlorine and Fluorine.

The constitution of Vanadic acid was for long unknown, the combining proportion but not the atomic weight of the metal having only been determined; but from the similarity of crystalline form of *Vanadinite* with the other minerals mentioned the thought was raised that Vanadic acid was similarly constituted to Phosphoric acid, its formula being

* c.f. Rammelsberg, Ber. der D. Chem. Ges. VII. 152.

V_2O_5, and not $V\,O^3$ as formerly supposed, and that the atomic weight was 51. This was conclusively verified by Roscoe's masterly and classic researches on the vapour densities of Vanadium compounds.

To show an extension of the Law, I will take the *Augite* family. *Augite* itself is to be regarded as an isomorphous mixture of Silicates of Calcia, Magnesia and protoxide of Iron of the general formula $M''SiO_3$, where M'' represents a *diad* metal; *Achmite* possesses the same form, but part of the *diad* metal M is replaced by the monad Sodium, two atoms of the latter for one of the former; this shows that Na'^2 is isomorphous with Fe'' Ca'' or Mg''. In this same group an instance of trimorphism occurs, it is that of the Rhombic *Enstatite*, the triclinic mineral *Babingtonite* $(Ca\,Fe)''SiO^3$ and monoklinic *Augite*.

But of pre-eminent interest alike to the petrologist and chemist is the relation existing between the triclinic felspars, *Albite* and *Anorthite*.

Crystallographically their forms are almost identical since these can be referred to axes of almost the same relative lengths and inclinations. Still there is an apparent dissimilarity in their chemical constitution namely :—

Albite .... $Na_2Al_2Si_6O_{16}$.
Anorthite .... $CaAl_2Si_2O_8$.

We have now between these two simple felspars, minerals of intermediary composition such as Oligoclase and Labradorite.

According to Tschermak and Vom Rath, the two simple felspars are isomorphous and in the two species last named we have isomorphous mixtures. Streng has pointed out how similarity of composition may be expressed, the principle appealed to by him being one capable of interesting and wide application. *

One must bear in mind as regards philosophical researches

* By writing the formula of Anorthite $Ca_2Al^2Al_2Si_4O_{16}$ and that of Albite $Na^2Si^2Al^2Si^4O^{16}$ the decavalent group Ca^2Al^2 is expressed as equivalent to *the decavalent group* Na^2Si^2 (Prof. Streng, Jahresb. f. Min. 1871, 598 and 715.

that the mere accumulation of facts is in itself of little value; they must be classed under theories or laws, which in their turn lead to the discovery of some more general principle. Even the chemist has what I may term an evolution of his elements to work out, this being now perhaps his guiding star in research.

The laws I have endeavoured to illustrate have even for this, great theoretical value and the apparent deviations from the laws may play their part in advancing chemical science.

Field Meeting, 20th August, 1881.

Held at Thurstaston Hill, conducted by Mr. C. E Miles. Attention was directed to the manner in which the strata had been tilted by faults, giving rise to a hill possessing scarped faces, the form of the hill being preserved by overlying hard beds. "Thor's Stone" was inspected, and the evidence of its isolated position being due to faulting was examined.

LIVERPOOL GEOLOGICAL ASSOCIATION.

5th September, 1881.

At the Meeting held this date, Mr. H. Bramall M. Inst., C.E., President, in the Chair, the following were proposed as members :—

Miss M. Wigzell, Messrs. George Scott, and L. C. Simpson.

The following Paper was read :—

THE LOWER CARBONIFEROUS DEPOSITS OF ANGLESEA,

BY ISAAC E. GEORGE.

GENERAL NATURE OF THESE DEPOSITS :—

By the Survey they have been divided into two series :— (1) The *Yellow Sandstones*; (2) the *Carboniferous Limestone.* The two series have much in common when we come to study their internal structure; but, as the surface of the conntry traversed by the Sandstones differs markedly in appearance from that presented by the Limestone district, the distinction is useful. The Sandstones are found at the base of the Limestones. Both series are represented in a small tract of Anglesea lying to the W. and S.W. of Redwharf Bay, and it is to this portion of the Island therefore, that I shall draw your attention. At their eastern boundary the lower Carboniferous rocks are heavily faulted against Archæan rocks. A general south-easterly dip and also the concealment of the *Yellow Sandstones* has been the result. On the western side, however, the beds flank the Old Red Sandstone. *Here, therefore,* a narrow strip of land several miles in length *is occupied by* the outcrop of the Sandstones. A fine coast

section of these strata at Lligwy Bay affords a good opportunity for observing their character.

The following is a reproduction of notes taken on the spot :—

"At western boundary the Carboniferous Sandstones faulted against Old Red, but probably not very much so. Junction of two planed down to sea-level, hence not observed. A little to the East one of members of the Sandstone group, a *Conglomerate*, is seen to form a cliff about 20′ high, but capped by Boulder clay. About 20 or 30′ of its thickness seen. Fragments very coarse, subangular; evidently not carried far, nor accumulated in a violent sea. Contains 3 classes of Pebbles. (1) *Quartz;* up to a few inches in diameter. Extremely abundant. (2) *Limestone;* very abundant also, though inferior in number to Quartz. In some cases 12 inches across. As a rule they are of moderate size, subangular, and flat. (3) A fine-grained yellow *Sandstone*, pebbles very abundant. Scarcely any other rocks represented. In the *Conglomerate* occur some thinnish bands of white *Quartz* grains, alternating with layers of *Mica*. These are weathering very rapidly through decomposition of contained *Iron*."

Further east on the Lligwy shore the Conglomerate is replaced by the more massive Grits, and these again in their turn by the carboniferous Limestone.

CHARACTER OF THE CARBONIFEROUS LIMESTONE :—

As already hinted, the history of the Carboniferous Limestone of Anglesea differs but little from that of the Sandstones, the deposition of which ushered in the period. Limestones certainly predominate, but they are sometimes so impure, and alternate so frequently with Grits and Shales that it is evident we have still to deal with littoral accumulations. The occasional abundance of Coralline remains, however, tell us that the waters were at times sufficiently deep and free from sediment to allow of the growth of these Zoöphytes.

As might be anticipated when dealing with rocks deposited under such circumstances, the strata are extremely local, appearing, expanding to a thickness of perhaps 12 or 20 feet,

then thinning out again, within the compass of 100 yards sometimes. Fine sections are seen on the western shore of Redwharf Bay, and I have here detailed some of the more interesting points worked out there :—

LARGE POTSTONES IN LIMESTONE :—

At Castle Point several thin seams of Limestone are crowded with large pot-shaped *nodules*, usually from two to four feet in width. They consist of a tough yellow *Sandstone*, occasionally Conglomeritic. In some small areas they may equal ⅓ of the entire bulk of a stratum. The surrounding Limestone matrix is plentifully studded with Quartz pebbles. As the Limestone platforms containing the nodules are scoured by the sea at tide time the results produced by marine denudation are highly interesting and instructive. The nodules being harder than the surrounding Limestone have withstood erosion better, so that large *potholes* have in most cases been excavated around them. Thus, they stand up in relief from the bottom of a circular or elliptical pit.

In the face of a high cliff at this spot I saw exposed a solitary *Potstone* which must have measured at least 10 feet in depth. It occurred in a thinly-bedded Limestone in which *Chert* was plentifully developed.

With but few intermissions the Limestone shore is marked by a well-developed line of cliffs throughout its whole length. Usually the descent of these is not a very difficult matter, as the Limestone is thinly bedded. This circumstance has given rise to a series of *platforms* leading upwards, like so many steps, from low-water mark to a height of, perhaps, 200 feet. But there are not wanting instances where the cliffs rise abruptly to a great height. In such cases a seam of clay or rotten Sandstone is generally present at the foot of the cliff; while below the clay-bed, and extending out towards the sea, is a wide shelf of rock on which repose numerous blocks of Limestone marking the gradual recession of the cliff above.

Standing at the base of one of these cliffs, looking at the enormous number of blocks on the strand, and the large size of some of the fallen fragments, the geologist realises that he

has before him one of the most impressive scenes presented by any coast line in England.

Good instances of caverns are rather rare on the shore. The few that I have noticed appear to owe their origin to the following exceptional circumstance; viz:—the abrupt descent to the sea of one of the cliffs already referred to, in which the strata are of about the same hardness throughout. Here the sea works its way into the Limestone between the *joints*, and produces *caverns* of varying size. The longest that I know of occurs at a spot where the cliff on the north side has receded faster than that on the southern side of an important joint. The sea is there pent up in a corner; and as there are always lots of pebbles at the foot of the cliff, the result has been the excavation of a cavern of very great length indeed.

THE GLACIAL PERIOD:—

Where the sea-cliffs are low, they are usually capped by *Boulder clay*. Small patches are also frequently found nestling on a protected ledge high up the face of a cliff. *Glacial Striæ* (bearing N.E. by S.W.,) occur now and then where the rocks bearing them have been protected from denudation. They are most frequently found at the mouths of small valleys trending N.E. by S.W., where these open out towards the sea. These facts accord well with the idea of an ice-sheet advancing from Cumbria, and ploughing its way diagonally across Anglesea.

SCENERY OF LIMESTONE DISTRICT:—

The Surface scenery of the Lower Carboniferous District is highly interesting and characteristic. Its bare platforms of Limestone, with their scarped edges, are a reproduction on a small scale of the scenery of the Pennine chain. As the strata rise gently towards the north-west their *escarpments*, with but few exceptions, are directed towards that quarter. Some of the higher platforms are strewn with large boulders. All those examined proved to be Limestone, so they are probably *erratic blocks* derived from some Limestone mass further away to the North. Denuding agents are busily at work reducing the size of the boulders as they rest on the

ground. Their surfaces are seen to be *deeply pitted* with holes, which are always increasing in size by solution of the Limestone walls which are nearly always in contact with rain-water. Here and there some of these large erratics have been collected into a convenient spot close at hand, and erected into altars (*Cromlechs*) by the earlier inhabitants of the Island.

To the north-west the Limestone ends abruptly in a *steep Escarpment* overlooking a long, *low-lying valley*, on the opposite side of which is the Quartzite mass of *Bodafon Mountain.*

The Eastern half of the valley is occupied by the outcrop of the *Carboniferous Sandstones.* The *Escarpments* of this formation are very subdued, only the slightest traces of a ridge being visible where a *hard grit* comes to the surface.

The black, scrubby character of the *vegetation* on this tract enables the outcrop of the formation *to be traced* by the eye for many miles north and south.

Fossils:—The remains of *Corals* and *Encrinites* are tolerably abundant in the Limestones. I have obtained small Encrinites from weathered cliffs near Castle Point. Corals also occur at the same spot, and also, more or less, through the entire thickness of Limestones as seen on the coast. *Producti* and *Spirifers* are common, but good specimens not met with.

DATE DUE
